FINAL DRAFT
REMEDIAL SYSTEMS DESIGN REPORT
INTERIM MEASURES SOIL AND
GROUNDWATER REMEDIATION
FORMER DIGITAL EQUIPMENT
CORPORATION FACILITY
SAN GERMAN, PUERTO RICO
DIGITAL PROJECT NO. 050-03018

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Engineers and Scientists

August 11, 1995
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Dear Mr. Zannos:

GZA GeoEnvironmental, Inc. (GZA) and Terra Vac, Inc. are pleased to provide you with the enclosed final draft of the Remedial Systems Design Report for the above referenced project. This report was prepared in accordance with our proposal dated May 12, 1995 as authorized by Digital's purchase order No. RC-304116. Please note that all engineering design work presented in this report was prepared under the supervision of a Puerto Rico registered professional engineer.

We trust this report is consistent with your needs. However, please do not hesitate to call any of the undersigned if you have any questions.

Very truly yours,

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Enclosure: Remedial Systems Design Report

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EXECUTIVE SUMMARY

This report presents the design of the proposed soil and groundwater remedial systems at the former Digital Equipment Corporation (Digital) Facility in San German, Puerto Rico. This report was prepared for submittal to the Environmental Quality Board of Puerto Rico (EQB) in accordance with the Overall Project Plan (OPP) and Interim Measures Proposal (IMP) for the site which were previously submitted to the EQB.[1,2] As stated in these documents, this work is being conducted as a voluntary Interim Measure in accordance with RCRA Corrective Action program requirements.

This report provides a summary of relevant site conditions; an evaluation of site specific Remedial Standards, including risk-based Media Protection Standards and regulatory based, Risk Management Standards; discussions of design criteria and performance specifications for soil and groundwater remedial systems; and proposed performance monitoring requirements for both systems.

The site consists of about 18 acres of land owned by the Puerto Rico Industrial Development Corporation (PRIDCO). There are three large manufacturing buildings on-site which were used by Digital for the manufacturing printed wire circuit boards until about 1992, when site operations were transferred to the Circo Caribe Corporation (Circo). Site operations include groundwater withdrawals through several on-site, high yield, water supply wells which are used to satisfy on-site process water needs.

Past uses of the site have resulted in the presence of chlorinated ethenes in soil and groundwater. These compounds were detected in the groundwater on a site wide level. Chlorinated ethenes were also detected in the vadose zone soils at a loading dock between Building 1 and Building 5 confirming that the loading dock is a source area.

Data indicate that current and past groundwater extraction has contained contaminants on-site. This conclusion is supported by the volume of water extracted which is over seven times the recharge for the portion of the drainage basin expected to contribute to groundwater flow through the site.

The findings of a human health and ecological risk assessment indicate that chlorinated ethenes in overburden and groundwater do not poses a significant human health or environmental risk to potential on-site and off-site receptors under current conditions of groundwater extraction for process water use.

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[1]GZA, November 11, 1995, Overall Project Plan, Voluntary Interim Measure, Former Digital Equipment Corporation Facility, San German, Puerto Rico.

[2]GZA, December 20, 1994, Interim Measures Proposal, Soil and Groundwater Remediation, Former Digital Equipment Corporation Facility, San German, Puerto Rico, Digital Project No. 05203018.

Although the quantitative risk assessment analysis indicate a condition of no significant risk to human health and the environment, EQB and RCRA require implementation of regulatory clean-up criteria (e.g. MCLs) as well as risk based criteria. Therefore, Digital has developed Risk Management Standards (RMS) to establish when the remedial systems should be shutdown based on physical and geochemical limitations associated with site conditions.

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To achieve RMSs, the existing groundwater treatment and extraction (containment) system will be upgraded to better treat and contain volatile organic compound (VOC) contaminated groundwater from the site. Treated groundwater will be used to satisfy Circo's current process water needs. Source control will be achieved by construction of a soil vapor extraction (SVE) system in the loading dock area to remove VOCs from vadose zone soils and thus reduce introduction of VOC's into the groundwater.

Groundwater containment will be achieved by intermittent pumping on demand from existing extraction wells W-1, and W-6, with a contingency to utilize well W-7 if needed to meet Circo's production water needs. VOC removal will be achieved by upgrading Circo's water treatment system with additional liquid-phased activated carbon adsorption treatment capacity, up to a peak flow of 200 gallons per minute.

As stated above, source control will be achieved with an SVE system in the loading dock area. VOC-laden soil vapor (air) will be extracted from the subsurface through three (3) shallow vapor extraction wells which will be installed in the loading dock area. The SVE system instrumentation, including a vacuum pump/blower, will be installed in an enclosed shed to be constructed on the loading dock.

After startup, the performance of both remedial systems will be monitored on a weekly basis for one month, on a monthly basis for one quarter, and on a quarterly basis for at least the first year of operation. Monitoring data will be used to optimize system performance as appropriate.

The proposed schedule for construction of the proposed remedial systems provides for systems construction and startup by the fourth quarter of 1995, which is consistent with the schedule presented in previous deliverables to the EQB.

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1.00 INTRODUCTION

This report presents the design for the soil and groundwater remediation systems to be installed at the former Digital Equipment Corporation (Digital) facility located in San German, Puerto Rico (site). The activities associated with the system design, installation and operation of the remedial system are being performed as a Voluntary Interim Measure following the format of the National Corrective Action Strategy under the Resource Conservation and Recovery Act (RCRA). This work will be conducted in accordance with the overall project plan[1] (OPP) and Interim Measures Proposal[2] for the site previously submitted to the Environmental Quality Board of Puerto Rico.

The remedial systems described in this report are designed to address soil and groundwater contamination by chlorinated ethenes identified during previous hydrogeologic investigations of the facility and will be conducted in accordance with the RCRA Corrective Action (CA) program requirements. As presented and discussed at a meeting with EQB on November 29, 1994 and in previous documents, the objectives of the proposed Interim Measure are to:

1. Treat and contain volatile organic compound (VOC) containing groundwater; and

2. Remediate VOC-containing vadose zone soils at the confirmed loading dock source area to reduce introduction of VOCs to the groundwater.

Digital proposes to implement a groundwater containment and treatment system utilizing existing bedrock production wells. VOCs in the pumped groundwater will be removed by activated carbon adsorption. The treated water will be used as industrial process water by the current facility lessee. Operation of the groundwater containment remedy will continue as long as the need for continued containment exists. Termination of active groundwater containment, in part or in whole, will occur when site-specific Remedial Standards have been met (see Section 2.00).

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[1] GZA, November 11, 1994, Overall Project Plan, Voluntary Interim Measure, Former Digital Equipment Corporation Facility, San German, Puerto Rico.

[2] GZA, December 20, 1994, Interim Measures Proposal, Soil and Groundwater Remediation, Former Digital Equipment Corporation Facility, San German, Puerto Rico, Digital Project No. 05203018.

The loading dock between Buildings 1 and 5 has been identified in previous investigations as a source of VOCs to groundwater. The system will remove VOCs from the vadose zone soils in this area using Soil Vapor Extraction (SVE). The system will operate until site-specific Remediation Standards have been met (see Section 2.00).

1.10 BACKGROUND AND OPERATING HISTORY

The site is located north of State Highway 362 in an industrialized area of San German, Puerto Rico. A Site Locus Plan is provided as Figure 1. The site was occupied from July 1968 into 1992 by Digital for single- and multi-layer printed wire board (PWB) manufacturing and module assembly. Since January 1993, the site has been occupied by the Circo Caribe Corporation (Circo) which has continued the PWB manufacturing processes. A plan showing major site facilities, and eight EQB identified "Solid Waste Management Units" is contained in Figure 2 (IMP).

Circo presently operates two eight-hour shifts of PWB manufacturing, employing 200 people. The module assembly operations conducted by Digital have not been continued by Circo. Circo's present operations are regulated under permits with EQB for air discharges, the Puerto Rico Department of Natural Resources for groundwater withdrawals and the Puerto Rico Aqueduct and Sewer Authority (PRASA) for industrial wastewater discharges to a POTW.

1.11 Site Hydrogeologic Setting

The site is located approximately 1,200 feet west of the Guanajibo River in a tributary drainage basin of about 54 acres in size, bounded by a steep northwest to southeast trending ridge to the north and a smaller hill to the south. Based on topography, the area of watershed which can be expected to contribute to groundwater flow through the site under ambient conditions is approximately 25 acres (Figure 1).

The site and vicinity have apparently been filled and graded during site development in 1968. Fill, consisting of clay and silt with lesser amounts of sand and gravel, has been encountered in thicknesses up to 23 feet in soil borings at the site. In a number of locations on-site, a silty clay topsoil layer has been encountered below the fill. The soils underlying the topsoil horizon were derived from natural chemical weathering (decomposition) of the underlying bedrock (saprolite). At the site, the depth to the water table ranges from approximately 5 to 35 feet below land surface (bls), placing the water table within the silt and clay fill and saprolite materials.

At the site, groundwater flow derived from precipitative recharge over the topographically highland areas to the north, east, and south, converges towards the pre-development topographic valley, and then flows northwest toward the Guanajibo River.

Average annual precipitation in the lower Guanajibo River drainage basin is about 56 inches. The EPA and the EQB reported a net precipitation (infiltration) of 14 inches per year for the site, which would imply on the order of 26,000 gallons per day of recharge contributing to groundwater flow through the site. Leakage from subsurface water lines, and perhaps discharge of chiller condensate and roof drainage add to flow beneath the site and have resulted in a local groundwater mound approximately 4 feet above the general groundwater flow conditions in the saprolite.

The hydraulic properties of the soil and rock beneath the site have been measured through pump testing, slug tests, and empirically assessed via grain-size distribution data. Considering the data in aggregate, GZA estimated a range of bulk hydraulic conductivity for saprolite and rock of 0.1 to 1 feet per day (3×10^{-3} to 3×10^{-4} cm/sec). Apparent transmissivity values estimated from pumping tests range from approximately 100 ft^2/day to approximately 1,800 ft^2/day. The results of these tests further demonstrate a consistent response for bedrock and saprolite well couplets indicating a significant degree of interconnection of these units, presumably through remnant bedrock fabric (jointing) in the saprolite.

1.12 On-Site Groundwater Withdrawals

Circo is currently operating under a Puerto Rico Department of Natural Resources Work Franchise (PRDNR) permit for groundwater withdrawal from on-site bedrock production wells of up to 49,920,000 gallons per year, or 192,000 gpd for a five-day work week (200 gpm based on two eight-hour shifts). Maintaining the groundwater supply is vital to Circo's operation. Bedrock wells W-1, W-3, W-6, and W-7 have been routinely used to provide this industrial process water supply. The current remedial strategy will focus the groundwater withdrawal from W-1 and W-6 only[3]. The drawdown from these wells has been projected to extend across the site in both overburden and saprolite based on pumping test data.

1.13 Distribution of Chlorinated VOCs

The two primary compounds detected include trichloroethene (TCE), and one of its breakdown compounds, cis 1,2-dichloroethene (DCE). VOCs were detected in groundwater samples from monitoring wells throughout the site, except for the eastern portion of the site. Historically, concentrations are greatest for samples collected from monitoring wells screened within the saprolite, ranging from 16 to a high of 41,000 micrograms/liter (ug/l) in OW-304 in 1993. Total chlorinated compounds in samples collected from the bedrock wells were significantly lower and ranged from 22 ug/l at W-1 to 360 ug/l at BR-308.

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[3]Well 7 can also be brought on line to meet Circo's water needs, if required.

The most recent groundwater monitoring event was completed from November 28 through November 30, 1994. A summary of VOC data from this sampling is provided in the IMP and the RFI Summary Report. GZA's ability to assess temporal and spatial trends in water quality based on the 1994 data was limited because a number of the saprolite wells were found to be dry due to dewatering by the bedrock pumping withdrawals. In general, the data suggested:

- a substantial decrease in total VOC concentrations for samples from shallow wells screened in fill or natural topsoil (OW-106, and OW-305); and
- an apparent increase in concentrations for samples collected from deep bedrock wells (W-5, W-6, W-7, and BR-308).
- Further support for the premise that groundwater extraction from the bedrock controls flow through the overburden.

Please refer to the IMP and RFI summary report for additional information, including a graphical comparison of existing groundwater quality information for the site.

1.14 Loading Dock Source Area

As presented in GZA's August 1992 Phase II Hydrogeologic Evaluation Report, potential sources of chlorinated ethenes in the subsurface were assessed by a combination of soil-gas survey and laboratory analysis of soil samples collected from a series of soil borings. Soil samples collected above the water table from two soil borings performed in the vicinity of the loading dock (B-413 and B-414) contained concentrations of total chlorinated compounds as high as 919 milligrams per kilograms (mg/kg) confirming the vadose zone in this area as a source of ongoing contamination to the groundwater.

The facility-wide investigation did not reveal evidence demonstrating that any of the eight areas preliminarily identified as SWMUs by the EQB were sources of chlorinated ethene contamination.

Please refer to the IMP and RFI Summary Report for additional information pertaining to GZA's assessment of potential source areas and including the results of the soil-gas survey.

1.20 DESIGN OBJECTIVES

The following sections discuss the design objectives for the groundwater containment and SVE systems.

1.21 Groundwater Containment System

The overall objective of the groundwater containment and treatment system is to improve interception, containment and treatment of VOC-containing groundwater. More specifically the pumping system is now designed to redirect groundwater extraction so as to further limit migration of the VOC plume; the treatment system design is augmented to meet the Remedial Standards and; these modification are designed so as to still provide Circo with a sufficient supply of process water for continued plant operations (200 gpm peak usage rate).

As discussed under Section 1.20 of the IMP, the "unit" of containment, or compliance limits are proposed as the approximate 14-acre area of contiguous land located on the north side of State Route 362. Although a high degree of containment is believed to already be afforded through past and on-going withdrawals of groundwater for production use on site, the objective of the system presented herein is to further enhance the containment effectiveness.

Specific objectives and performance standards to be met by the groundwater treatment and containment system are to:

1. Achieve risk based groundwater remedial standards.

2. Contain VOC-contaminated groundwater by establishing and maintaining hydraulic gradients so groundwater which would ordinarily migrate from the property is captured for treatment;

3. Treat the intercepted groundwater to remove VOCs to the degree necessary to meet the Remedial Standards and allow use of the water for on-site production needs, ultimately meeting the pretreatment requirements for the industrial wastewater discharge to the PRASA POTW.

4. The system shall be capable of operating within the presently permitted maximum daily and annual process water needs of the existing operations conducted by Circo, up to a peak rate of 200 gpm.

5. Monitor groundwater levels and quality as well as remediation system performance to assess containment and temporal/spatial trends in groundwater concentrations. The performance monitoring information will be used to evaluate the adequacy of the system, and to make decisions regarding possible future termination of containment and treatment as a remedial measure.

1.22 SVE System

The SVE system is designed to remove VOCs from the soils above the water table in the loading dock area.

The SVE system has been designed to meet the following:

1. Remove VOCs from the loading dock source area until site-specific Remedial Standards have been met; and

2. Achieve the desired remediation results within a reasonable time frame (less than five years).

1.23 Design Approach

Turnkey design and construction of the proposed remedial systems will continue to be implemented using the Observational Method as presented in Dean and Barvenik[4]. Under this design approach, the existing site data and Terra Vac's experience at similar sites in Puerto Rico have been used to formulate a conceptual model that describes the expected subsurface behavior. The remedial system was then designed based on this conceptual model with Contingency Plans established to address uncertainty in the original conceptual model. The system, as proposed herein, will then be installed, operated and monitored to evaluate if the original conceptual model was correct and the system performs as designed. This initial operational period is effectively a pilot test of the full scale system. Given that the entire system is evaluated as installed in the field, the Observational testing provides the most accurate evaluation of performance. If the system does not perform as expected, it will be modified based on the new operational data to achieve the required performance. These modifications, if required, have been anticipated earlier in the contingency planning.

The Observational Method is consistent with the RCRA Voluntary Interim Measure Strategy and provides the appropriate mechanism to implement the proposed remedial action in the shortest possible timeframe while still providing assurances of sufficient operational performance and cost control.

[4] Dean, A.R. and M.J. Barvenik, "Use of the Observational Method in the Remedial Investigation and Cleanup of Contaminated Land," The Seventh Geotechnique Symposium - Geotechnical Aspects of Contaminated Land, sponsored by the Institution of Civil Engineers, London, Volume XLII, Number 1, March 1992.

1.30 ORGANIZATION OF REPORT

This document presents the design for the groundwater containment system and soil vapor extraction system. Section 2.00 presents the Remedial Standards for the groundwater containment/treatment system and the SVE system. Section 3.00 of this report discusses the groundwater containment and treatment system, including the conceptual design, the system performance specifications and design criteria, the system description, the O&M requirements, and the performance monitoring plan. Section 4.00 provides the above information for the SVE system. Section 5.00 discusses the project schedule.

2.00 REMEDIAL STANDARDS

The appropriate remedial standards for this project are divided into two major types; risk based standards and risk management standards. The first, and most critical, are the site specific, risk based Media Protection Standards (MPSs). Consistent with RCRA corrective action methodology, these standards represent concentrations in soil and groundwater at the site which will not cause concentrations at the identified exposure points to exceed acceptable risk limits to human health or the environment. Risk Management Standards, as discussed in Section 2.20., are performance based standards which define when the remedy should be discontinued given the physical and geochemical constraints of the site that limit further reductions in contaminant concentrations.

2.10 MEDIA PROTECTION STANDARDS

For carcinogenic effects, we calculated Media Protection Standards (MPSs) which correspond to a 10^{-6} (one in one million) incremental risk of an individual developing cancer over a lifetime as a result of exposure to a potential carcinogen in a given environmental medium. For noncarcinogenic effects, we calculated MPSs that correspond to a hazard index (HI) of 1.0, the level of exposure to a chemical, or chemical with the same target effect, in a given environmental medium below which it is unlikely for even sensitive populations to experience adverse health effects. The MPSs for each chemical were calculated based on significant exposure pathways for a given medium, such as dermal contact and incidental ingestion of soil. U.S. EPA Ambient Water Quality Criteria for freshwater aquatic life and for human health with respect to fish consumption were used to assess potential risk to the Guanajibo River and associated receptors.

GZA developed Pathway Specific Concentration Limits (PSCLs) for use in establishing MPSs for soil and groundwater. PSCLs are concentrations developed based on site-specific considerations and pathways by which identified receptors may be exposed to contaminants. PSCLs for soil and groundwater were calculated based on current and

foreseeable future site use, identified human and ecological receptors, potential exposure points and exposure pathways, toxicity and chemical-specific information for chemicals of concern, and target risk levels. Appendix B presents the methodology and equations used to calculate these site-specific, PSCLs. The lowest PSCL for a contaminant in a given medium (i.e., soil or groundwater) was selected as the MPS.

2.11 Soil

2.11.1 Calculation of Pathway Specific Concentration Limits For Soil

As described in Appendix B, utility workers may contact constituents in soil within the loading dock area during subsurface excavation for repair/installation of utility lines. Consequently, we calculated soil PSCLs based on potential dermal contact and incidental ingestion exposure to surficial and subsurface soil (0 to 8 feet below ground surface) within the loading dock area by hypothetical (future) utility workers. PSCLs for soil were calculated for the following contaminants detected in soil samples collected from borings completed within the loading dock area: cis 1,2-dichloroethene (cis 1,2-DCE), trans 1,2-dichloroethene (trans 1,2-DCE), and trichloroethene (TCE). Refer to Table 1 for soil PSCLs.

2.11.2 Identification of Media Protection Standards for Soil

The PSCLs for cis 1,2-DCE and trans 1,2-DCE in soil were based on their noncarcinogenic effects. The PSCLs for cis 1,2-DCE and trans 1,2-DCE represent the MPSs for soil given that no carcinogenic effects are documented in the literature. The PSCL for TCE in soil was calculated based on carcinogenic effects. The PSCL for TCE represents the MPS for soil given that no noncarcinogenic effects are documented in the literature. MPSs for soil are presented below.

Contaminant	Media Protection Standards for Soil (mg/kg)
cis 1,2-DCE	171,000
trans 1,2-DCE	342,500
TCE	21,800

2.11.3 Comparison of Soil Conditions Within the Loading Dock Area to Media Protection Standards for Soil

To evaluate whether the levels of VOCs in soil meet site-specific MPSs, we compared maximum detected concentrations in soil within the loading dock area to these MPSs. The maximum detected concentrations of cis 1,2-DCE, trans 1,2-DCE and TCE in soil from this area, at depths of 0 to 8 feet below ground surface, are below the site-specific MPSs for these contaminants in soil. Based on the above

analysis, a condition of no significant risk currently exists for the source area soils in the loading dock[3].

2.12 Groundwater

For groundwater, we calculated both risk-based and AWQC-based PSCLs incorporating a number of simultaneous exposure pathways (see Appendix B). Exposure to chemicals in groundwater may potentially occur via both direct and indirect routes, including: (1) dermal contact exposure to groundwater by hypothetical (future) utility workers, (2) inhalation of process water liberated VOC vapors in indoor air by facility workers who are employed in site buildings, and (3) potential migration of contaminants in site groundwater to the Guanajibo River with subsequent consumption of fish from the river. PSCLs for both overburden and bedrock groundwater were calculated. PSCLs for overburden groundwater were based on potential utility worker dermal contact exposures, fish consumption exposures for local residents, and protection of fresh water aquatic life. PSCLs for bedrock groundwater were based on facility worker inhalation exposures, fish consumption exposures for local residents, and protection of fresh water aquatic life.

2.12.1 Risk-based Pathway Specific Concentration Limits

Risk-based PSCLs for groundwater were calculated based on potential noncarcinogenic and carcinogenic effects associated with the following two exposure pathways: (1) dermal contact exposure to VOCs in site groundwater by utility workers and (2) inhalation of VOC vapors in indoor air by facility workers associated with use of groundwater as process water. We calculated PSCLs for shallow overburden groundwater for the following contaminants detected, based on assumptions regarding potential dermal contact exposures to groundwater by utility workers: chloroform, cis 1,2-DCE and 1,2-dichloroethane (1,2-DCA). We calculated PSCLs for deep bedrock groundwater for the two primary VOCs detected, cis 1,2-DCE and TCE, based on assumptions regarding potential inhalation of VOC vapors in indoor air associated with use of groundwater from pumping wells as process water.

[3]As subsequently discussed in Section 2.00 - Risk Management Standards, the loading dock source area soils still require remediation to limit their ongoing contamination of the groundwater via leaching of infiltration.

2.12.2 AWQC-based Pathway Specific Concentration Limits

PSCLs for groundwater discharging to the Guanajibo River[6] were calculated based on AWQCs for the protection of (1) freshwater aquatic life and (2) human health with respect to fish consumption from the River. The lowest of the available and applicable AWQC for each contaminant was selected. We calculated PSCLs for overburden and bedrock groundwater for contaminants detected in groundwater collected from monitoring wells which represent the Point Of Compliance (i.e., in monitoring wells W-1, W-6, W-7, BR-308, OW-102, OW-304, OW-401, OW-404U, OW-404L, and OW-405). The Point of Compliance is defined as the entire downgradient portion of the site through which groundwater from the site flows off site and contributes to surface water discharge. Given that the contaminant concentration in the river would be proportional to the entire contaminant mass flux, the PSCLs represents an average concentration indicative of the mass flux leaving the site. An exceedance of this concentration by a single monitoring well does not constitute an exceedance of the PSCL.

2.12.3 Identification of Media Protection Standards for Overburden Groundwater

PSCLs for overburden groundwater were calculated based on (1) dermal contact exposure to VOCs in site groundwater by utility workers and (2) AWQCs for the protection of (a) freshwater aquatic life and (b) human health with respect to fish consumption. The MPSs for each contaminant in overburden groundwater was selected based on the lowest PSCL calculated for a given contaminant considering these potential exposures. MPSs for overburden groundwater are presented below.

Contaminant Media Protection Standards for Overburden Groundwater (ug/l)

1,1-Dichloroethane	29,000,000
1,1-Dichloroethene	2,500
1,2-Dichloroethane	50,000
Chloroform	17,000
cis 1,2-Dichloroethene	3,500,000
trans 1,2-Dichloroethene	14,600,000
Methylene Chloride	157,500,000
Tetrachloroethene	111,000
Trichloroethene	11,000

[6]The VOCs of concern at the site have not been detected in surface water or sediment of the river. This is as would be expected given that the existing pumping of the process wells removes far more groundwater than the recharge capacity of the drainage basin and thus effectively contains the plume on site (see Section 1.11). Potential impacts to the river, as computed herein, are based on a hypothetical future condition where the facility has closed and the process wells are shut down permanently.

2.12.4 Identification of Media Protection Standards for Bedrock Groundwater

PSCLs for bedrock groundwater were calculated based on (1) potential inhalation of VOC vapors from bedrock groundwater in indoor air by facility workers who are employed in site buildings and (2) AWQCs for the protection of (a) freshwater aquatic life and (b) human health with respect to fish consumption. The MPSs for each contaminant in bedrock groundwater were selected based on the lowest PSCL calculated for a given contaminant considering these potential exposures. MPSs for bedrock groundwater are presented below.

Contaminant Media Protection Standards for Bedrock Groundwater (ug/l)

1,1-Dichloroethane	30,000,000
1,1-Dichloroethene	3,500
1,2-Dichloroethane	3,800,000
Chloroform	237,000
cis 1,2-Dichloroethene	8,700
trans 1,2-Dichloroethene	2,200,000
Methylene Chloride	24,000,000
Tetrachloroethene	17,000
Trichloroethene	26

2.12.5 Comparison of Groundwater Conditions to Media Protection Standards for Overburden and Bedrock Groundwater

To evaluate whether VOC concentrations in shallow and deep groundwater meet site-specific MPSs for groundwater, we compared maximum detected concentrations in groundwater to applicable MPSs as described below.

Concentrations of cis 1,2-DCE and TCE detected in process water were compared to MPSs for bedrock groundwater from which the process water is extracted. Results of this comparison indicate that VOC levels in the process water do not exceed the MPSs. Additionally, a comparison of maximum detected concentrations of VOCs on portions of the site where depth to groundwater is 0 to 8 feet below ground surface (i.e., locations which represent potential exposure points for hypothetical (future) utility workers) indicates that these concentrations are below MPSs for overburden groundwater. Furthermore, a comparison of maximum concentrations in overburden and bedrock groundwater collected from monitoring wells which represent the Point Of Compliance (i.e., for discharge of groundwater to the Guanajibo River) indicates that these concentrations are also below applicable MPSs.

Based on the above analyses, neither the overburden nor the bedrock groundwater pose significant human health or environmental risk to potential on-site or off-site receptors under the current conditions of groundwater extraction for process water use. It should be noted that the risk assessment did not quantitatively assess the possible risk to the two unregistered private wells which may exist in the El Convento Housing District located 300 feet to the south of the site (based on an unsubstantiated verbal report) if the process wells are no longer pumped[7]. Even with the process wells shut down, it is not expected that the groundwater would flow in this direction. However, if these private wells exist and were pumped (illegal) at a high enough flow rate, some impact by site contaminants could be possible. As such, more formal institutional controls may warrant consideration in the future if the facility was permanently closed.

2.20 RISK MANAGEMENT STANDARDS

Although the analyses conducted indicate that the MPSs have all been met at the site and a condition of no significant risk to human health and the environment currently exists, the EQB and RCRA require implementation of remediation based on regulatory based cleanup criteria (e.g. MCLs), as well as the risk based criteria. Given the nature of subsurface conditions (e.g. fracture bedrock) achieving regulatory standards is highly unlikely, therefore, we have developed Risk Management Standards (RMSs) to establish when the system should be shutdown based on the physical and geochemical limitations associated with site conditions[8]. Concentration Limited RMSs have been defined as the continued reduction of contaminant concentrations below MPSs to that point where additional reductions are no longer practicable given the limitations of the current technology (asymptomic condition). Further removal of contaminant mass may still be possible but will not further reduce risk to human health or the environment which is dependent on contaminant concentrations in the environmental media.

The following subsections present the methodology for deriving quantitative Risk Management Standards (RMSs) and then provides specific application of these standards to soil and groundwater.

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[7]Under process well pumping conditions, the data indicate that the compounds found on site are contained on site. As such, no complete exposure pathway to these unregistered wells, if they exist, is expected to exist. Therefore, these wells would not be receptors under current pumping conditions.

[8]In this case, it is anticipated that groundwater system shutdown would only result in removal of the activated carbon canisters (see Section 3.00). It is probable that groundwater containment will still be maintained given continued use of the facility and thus the process wells.

2.21 Calculation of Concentration Limited Risk Management Standards

To compute the contaminant concentrations beyond which further reductions are not practicable, a model describing the rate of change of contaminant concentrations during the remedial action must be established. Based on past experience with other similar sites, the mathematical model which appears to best describe this behavior is a first order exponential decay curve of the general form $C=(C_o-C_f)e^{-kt}+C_f$. The initial concentration, C_o, corresponds to that concentration defined by the above equation at t=o (startup of the remedial action). The final concentration, C_f, corresponds to the level asymptotically approached by the curve at t = infinity. t is the time since the start of remediation (time is often represented as pore volumes of groundwater or soil gas extracted given that this is the mechanism driving reduction in concentrations), k is the exponential rate constant and C is the most current contaminant concentration.

Once the remedial action has been initiated and performance data collected, the first order exponential delay curve which best fits these data is determined using a non-linear numerical curve fitting algorithm (see Appendix A). Each time a new set of data is collected, a new best fit curve is established. Data collected shortly after startup of the remedial action determines the shape and decay rate of the upper limb of the exponential curve and the primarily controls the fitted value of C_o. The data collected later in the remedial process falls on the lower limb of the curve and primarily controls the projected value of C_f.

The Concentration Limited RMS is achieved when the contaminant concentration, C, reaches the Point of Diminished Return (PDR) which is defined as the contaminant concentration at which 90 percent of the projected ultimate reduction in contaminant level (C_o-C_f) has been reached.

2.22 Risk Management Standards for Soil

Soils in the loading dock will be remediated using soil vapor extraction (SVE). The three primary VOCs detected in the unsaturated zone soils in this area are trans-1,2-DCE, cis-1,2-DCE and TCE. The maximum concentration detected for each of these compounds is currently over an order of magnitude below the applicable MPSs. As such, RMSs will be adopted to assess when the remedial system can be shut down. Given that TCE concentrations are typically over an order of magnitude greater than the other compounds and it is the least volatile, TCE will be used as the index compound.

With startup of the SVE system, TCE concentrations in the extracted soil gas are expected to decrease in an exponential manner as the VOCs are removed from the soils. TCE concentration data will be obtained from the extraction wells and a best fit exponential curve will be developed. The Concentration Limited RMS will be achieved when the Point of Diminished Return has been reached and the SVE system will be shutdown.

GZA

2.23 Risk Management Standards for Groundwater

Although system upgrades are proposed herein, the groundwater remedial action at the site has effectively been ongoing for a number of years; as discussed in the IMP, existing process water extraction is already containing the plume. The contaminant concentrations in overburden and bedrock groundwater are currently below the appropriate MPSs, as discussed in Section 2.12.5. As such, RMSs will be developed for the extracted process water to assess when the remedial action can be terminated.

In this case (as compared to the case for soils), the method for establishing Concentration Limited RMSs must be modified given that contaminant concentration data was not collected for the process water during the "startup of remediation". Therefore, the first order exponential delay curve cannot be established. As such, the influent concentration[9] will be plotted vs. time for a period of one year[10]. The system will be shut down if these data can be fitted by a first order exponential delay curve with the data falling along the lower limb of that curve as it approaches a zero slope representing an asymptomic condition.

It is expected that groundwater containment on site will still be maintained by the ongoing pumping of the process wells for manufacturing purposes; although given that the MPSs have already been achieved, there is no reason that operation of the process wells must be maintained. If the process wells were permanently shut down, post-facility closure institutional controls may be prudent to ensure that some unforeseeable future off-site groundwater pumping[11] does not changed the hydrological regime assumed herein.

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[9]Given that the concentrations of the two compounds previously detected (cis-1,2-DCE and TCE) were nearly equal (12 and 14 ppb, respectively), the concentrations of these two compounds will be added together and plotted as total VOCs.

[10]As previously proposed in the IMP.

[11]Such as illegal pumping of unregistered private wells, if they exist.

3.00 GROUNDWATER CONTAINMENT AND TREATMENT SYSTEM

3.10 CONCEPTUAL MODEL

Development of the conceptual design for the groundwater containment and treatment component of the voluntary corrective action was based on the subsurface conceptual model contained in the IMP, as well as available information regarding:

- aquifer properties and apparent well yields;
- facility process water needs and permit limits;
- observed aquifer response to pumping;
- the apparent distribution of VOCs in groundwater; and
- a preliminary groundwater engineering assessment.

The groundwater engineering work conducted to date includes:

- compilation, review and assessment of well logs and past aquifer testing results;
- graphical assessment of data collected during performance of a 48-hour pumping test on existing production well W-6; and
- an assessment of theoretical aquifer response to withdrawals using two-dimensional analytical solutions.

A summary of relevant information regarding each of the listed considerations is included in the following subsections. These data and the resulting conceptual model form the basis for the design using the Observational Method approach.

3.11 Aquifer Properties and Apparent Well Yields

The hydraulic properties of the soil and bedrock beneath the site have been measured via pumping tests, slug testing, and empirically evaluated through grain-size distribution data. Considering the data in aggregate, GZA estimates a range of bulk hydraulic conductivity for saprolite and bedrock of 0.1 to 1 feet per day (3 x 10-3 to

3 x 10-4 cm/sec). Apparent transmissivity values estimated from the pumping tests of the existing production wells are summarized as follows:

Well Designation	Apparent Transmissivity	Comments
W-1	210 ft^2/day	Reportedly a 350 -foot deep well, depth of casing unknown; Pump testing conducted by GZA in 1983
W-2	no data	Well no longer in use
W-3	no data	Unknown depth and construction. According to Circo, well used to produce between 2,000 and 62,000 gallons per day
W-4	no data	no longer in use
W-5	300 to 500 ft^2/day	8-inch diameter well, drilled 350 feet deep, cased to 57 feet, approximately 0 feet below rock
W-6	100 to 200 ft^2/day	Reportedly a 407 foot deep well, cased to a depth of 80 feet, with rock at about 35 feet
W-7	no data	Depth and construction unknown, reportedly used for production of up to 34,000 gallons per day
BR-308	1,800 ft^2/day	Six-inch diameter, 164 foot deep monitoring well

The locations of each of these production wells are shown on the Site Layout Plan, Figure 3.

3.12 Magnitude of Circo's On-Site Groundwater Withdrawals

Circo is currently operating under a groundwater withdrawal permit for up to 49,920,000 gallons per year or 192,000 gpd for a 5-day work week. A summary of available data concerning Circo's past withdrawals is presented below.

Well	Total Depth (ft)	In Use	Pumping Rate (gpd)		
			Average	Minimum	Maximum
W-1	350	yes	124,000	103,400	157,800
W-2	N/A	no	N/A		
W-3	N/A	yes	3,900	2,100	4,000
W-4	N/A	no	N/A		
W-5	350	no	N/A		
W-6	407	yes	77,200		95,400
W-7	N/A	yes	24,700	8,400	43,400
Total Daily Pumping Rate			154,000	113,900	192,000

Notes:

1. N/A indicates information is unknown or otherwise not available.

2. Circo's water franchise permit allows a maximum withdrawal of groundwater of 192,000 gpd; thus, although individual wells may be pumped at the maximum rates noted above on separate days, the total groundwater withdrawal does not exceed 192,000 gpd.

It should be noted that Circo's maximum permitted withdrawal, and actual average water consumption are greater than the estimated cross sectional groundwater flow through the site. As such, the existing groundwater withdrawals should be capable of capturing VOC-containing groundwater generated within the site.

3.13 Observed Aquifer Response

Results of aquifer pumping tests conducted by GZA indicate a high degree of interconnection of the bedrock and overlying saprolite and suggest that the area of influence of the operating wells extends across the site in both units.

As presented in IMP and RFI, after 48 hours of pumping a single production well (W-6) at only 50 gpm, potentiometric levels in saprolite indicate a bimodal, elongated area of influence. This drawdown pattern likely reflects the subparallel and perpendicular fracture orientation relative to the pre-development topographic valley. The data indicate a radius of influence on the order of 470 feet with a capture zone radius of about 200 to 250 feet, extending half of the distance across the site. The upland area east of W-6, corresponding to an apparent bedrock high, is manifested as a leaky boundary.

The observed response during pumping of W-6 is supported by analytical groundwater engineering which suggests that drawdown for existing groundwater withdrawals from wells W-1 and W-6 should overlap encompassing the width of the site, normal to the natural groundwater flow direction.

Results of water level monitoring in 1994 support the assertion that the effects of Circo's groundwater withdrawals result in substantial drawdowns across the site in the saprolite. We understand that for months prior to this water level event, Circo had been withdrawing an average of about 154,000 gpd from wells, W-1, W-7, and W-3. For several days prior to, and at the time of the event, W-1 was down for repairs, and process water was being withdrawn from W-6, W-7, and W-3 only.

As discussed in the IMP and RFI Summary Document, compared to the ambient (non pumping) water level information from April 1993, the water level information from the 1994 event indicate a site-wide decline in saprolite water levels, with a maximum of about 28 feet near the center of the site at well OW-403. Nine wells screened either in saprolite, or the upper 10 feet of rock were observed to be dry, with an apparent decrease in water level of greater than 3 to about 22 feet. In aggregate, the water level information suggests a pattern of groundwater flow that is similar to that observed for the 1993 pumping test conducted on W-6. The data suggest a net inward hydraulic gradient from 0W-404, and OW-401, towards the pumping wells.

3.14 Apparent Distribution of VOCs in Groundwater

Figure 3 of the RFI Summary Report depicts the distribution of VOCs found in groundwater in September 1992, February 1993 and November 1994. As indicated on the figure, the most prevalent VOC is trichloroethene (TCE), with 1,2-dichloroethene (DCE), a primary TCE breakdown product, as the next most prevalent compound. TCE was generally detected in wells downgradient of the only confirmed source area (loading dock).

3.15 Design

The design for the groundwater containment portion of the system includes the use of existing wells W-1 and W-6 for water withdrawal (as part of the contingency plan under the Observational Method approach, well W-7 can also be brought on-line to meet Circo's water demand if required. However, it should be noted that production wells located up and cross gradient of the facility (e.g., W-3, W-4 and W-5) should no longer be used). Wells W-1 and W-6 will pump water through the existing piping manifold to the existing water treatment area. The existing down-hole pumps and controls will be used (although W-1 is currently not operational, it is under repair and expected to be operating shortly); the flow totalizers for each well will be upgraded as necessary with new totalizers.

Continuous operation of wells W-1 and W-6 should not be required to maintain containment effectiveness; pumping as required to provide for the current plant operations (approximately 200 gpm during two 8 hour shifts) should be sufficient. As such, it is anticipated that groundwater will not be extracted during the non-production hours at night nor during weekends. Occasional shut downs for 1 week should also not significantly impact containment effectiveness. However, prolonged plant shut downs for greater than 2 weeks will likely require provisions to maintain a reduced level of groundwater extraction.

The existing downhole pumps will discharge into the existing 25,000-gallon equalization tank. The existing system pressure demand pumps will transfer water from the equalization tank through the sand filters (to remove total suspended solids), and then to the water treatment system on an as demand basis. Additions to the existing water treatment system will consist of three new high-pressure activated carbon absorbers connected in series with the two existing carbon absorbers. The new canisters will be used as the primary adsorption vessels, while the two existing vessels (connected in parallel) would be used as back-ups in case of break-through of the primary vessels. The process flow diagram is shown as Figure 2.

3.20 SYSTEM PERFORMANCE SPECIFICATIONS AND DESIGN CRITERIA

The following section discusses system performance specifications and design criteria for the groundwater containment and treatment system.

The existing and new components of the groundwater containment and treatment system must be able to provide process water to Circo's operations at flow rates up to the peak maximum flow of 200 gpm. The new carbon contactors will reduce VOCs in the extracted groundwater to below the Remedial Standards (see Section 2.00), allowing process use of this water, with final discharge to the POTW.

Average monthly pumping rates of at least 40 gpm will be required to maintain effective groundwater containment. Groundwater containment will be verified via establishment and measurement of hydraulic gradients.

The redundant municipal water supply capability will be used to maintain an adequate supply of water to Circo in case of equipment maintenance or malfunction. In particular, the system design and operational strategy must allow for the shut down of any one of the production wells.

3.30 SYSTEM DESCRIPTION AND SPECIFICATIONS

The following sections detail the equipment specifications for the size and capacity of the groundwater containment and treatment system components.

3.31 Groundwater Extraction Wells

The existing production wells W-1 and W-6 will be utilized for extraction of VOC-containing groundwater. Well W-7 will be brought on-line if needed to satisfy Circo's process water demands. This is shown schematically on Figure 2. Figure 3 shows the locations of the three wells.

Wells W-1, W-6, and W-7 are well positioned relative to the natural groundwater flow direction. W-1 is apparently the highest yield well of those presently used for production of facility process water, and has been shown to intercept VOCs at 14 to 36 ug/l under pumping conditions. W-6 is located closest to the loading dock source area. The most recent sampling indicated 395 ug/l for a sample collected during pumping of W-6. W-7 is the most downgradient production well location and will be used to supplement W-1 and W-6 if necessary.

The initial groundwater recovery estimates per well are:

Well	Yield (gpm)
W-1	125
W-6	75
W-7	Up to 40 if required

Because the total peak flow rate of 200 gpm is much greater than that necessary for containment of the VOC plume, routine shutdown of the extraction pumps overnight or on weekends is permissible. However, shutdowns of longer than one week may jeopardize the containment effectiveness.

3.32 Groundwater Extraction Pumps

The existing electric submersible groundwater extraction pumps will be utilized for extraction of VOC-containing groundwater. The groundwater extraction pumps will be controlled by the level controls in the existing 25,000 gallon equalization tank.

3.33 Groundwater Extraction Manifold

The existing groundwater manifold will be utilized for the transfer of extracted groundwater through the system. The existing groundwater manifold is constructed of 4" steel piping. From the equalization tanks to the process water distribution system, the piping is welded steel.

The flow totalizers located at wells W-1, W-6, and W-7 will be upgraded as required with new flow totalizers. The new flow totalizers will be paddle-wheel type meters, with local indication. They sball be rated for flows up to 150 gpm; and have indicating digits to at least millions of gallons.

3.34 Groundwater Equalization Tank

The extracted groundwater will be pumped using the existing piping network to the existing 25,000 gallon tank for flow equalization prior to entering the treatment system, since it provides over three hours of residence time at the maximum sustained pumping rate of 192,000 gpd as well as control of the extraction pumps. The existing level controls will control the operation of the groundwater extraction pumps.

The two existing pressure demand transfer pumps will pump the water from the equalization tank through the sand filters and existing carbon contactors as they do currently. While these pumps will also be called on to overcome the head loss associated with the new carbon contactors, the existing head loss associated with the existing contactors will be reduced by connecting them in parallel rather than the existing series configuration.

3.35 Groundwater Treatment System

VOCs will be removed from the water by liquid phase carbon. Circo currently has a liquid phase carbon system for removing VOCs from extracted groundwater. The system includes two 5-foot high carbon contactors, one 4 feet in diameter and one 5 feet in diameter, holding a total of approximately 160 cubic feet of carbon. At a design flow rate of 192,000 gpd through this system, the average contact time between the water and the carbon is 3.6 minutes assuming a carbon porosity of 0.40. The recommended contact time for VOC removal is seven minutes. Circo's system will

therefore be upgraded to treat the proposed groundwater flowrates by adding three new high-pressure carbon contactors (connected in parallel) between the existing sand filters and the existing carbon contactors. Figure 4 shows the proposed layout of the new carbon contactors, and Figure 5 shows a profile of the contactor piping and valving.

Each of the new carbon contactors will contain approximately 1,700 pounds of liquid phase granular activated carbon (LGAC). GZA assessed carbon usage for two influent VOC concentrations. The likely average concentration is approximately 30 ug/l, based on the influent sample collected on December 1, 1994 and on the analytical data for wells W-1 and W-6. GZA also developed a conservative estimate for carbon usage based on an influent concentration of 300 ug/l.[12] The likely carbon efficiency for these two influent concentrations are 1 and 3 percent, respectively.[13] The carbon usage rate for the two scenarios ranges from 1,800 to 6,000 pounds per year. It is therefore unlikely that the carbon changeout frequency will be greater than one year, unless influent concentrations approach 300 ug/l.

The new set of carbon adsorbers will be manifolded in series with the two existing carbon adsorbers. The new adsorbers will be used as the primary adsorption vessels, while the two existing vessels (connected in parallel) will serve as back-ups in case of breakthrough of the primary adsorber.

The carbon adsorption vessels will have a minimum pressure rating of 75 psig. They will be rated for a maximum pressure drop of 0.6 psig at 75 gpm per vessel. These vessels may be constructed of epoxy-coated steel or wound FRP fiberglass. Each vessel will have a design flow of 100 gpm, and have an approximate size of 48 inches in diameter and 93 inches tall. Two and one half-inch female pipe thread (FPT) inlet, outlet, and drain connections will be provided.

3.40 O&M REQUIREMENTS

After system start-up and shake-down, Terra Vac will develop an operations manual that will include recommended operating specifications, performance standards and monitoring, routine and preventative maintenance, and troubleshooting information.

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[12] The highest observed concentration from the extraction wells was 360 ug/l at W-6.

[13] Carbon efficiency is the mass of contaminant adsorbed divided by the mass of carbon saturated with that contaminant. The estimates are based on adsorptive isotherms presented in Stenzel and Merz (1989), "Use of Carbon Adsorption Processes in Groundwater Treatment," Environmental Progress, v. 8, n. 4, pp. 257-264.

This manual will be submitted to Digital for review and approval, with the final edited version also submitted to Digital and Circo.

3.41 Operations and Monitoring

During the initial one-to-three month operating period, GZA and Terra Vac will evaluate the system performance using an enhanced monitoring schedule. The data gathered during this period will be use to optimize performance of both the groundwater containment and treatment system and to evaluate if the system, as proposed herein, meets the operational design objectives, consistent with the Observational Method approach adopted for this project. If the system does not adequately achieve the operational objectives, modifications will be recommended and constructed.

For the portion of the first month of operations after the one week start-up period, site visits will be conducted weekly. During each visit, the groundwater system monitoring will include reading the flow meters at each pumping well, taking water samples from the water treatment system influent and effluent and manually gaging selected wells for depth to groundwater. The water samples will be sent to a Puerto Rico-certified laboratory for analysis by EPA Method 8010. At the end of the month, the information gathered from the data loggers installed during the start-up period will be downloaded, and the transducers will be removed.

During the remainder of the first quarter, site visits will occur monthly. Monitoring will be conducted as described above for the weekly visits.

Following the first quarter, routine site visits and monitoring events will be conducted quarterly. Routine operations will include system cleaning and adjustments, routine and preventative maintenance, and repair of system components as required. Because of the low VOC loading rates predicted, changeout of the liquid-phase activated carbon is not expected to occur during the first year (see Section 3.30.5).

Water treatment system influent and effluent samples will be drawn and submitted to a Puerto Rico-certified laboratory for analysis by EPA Method 8010. Groundwater containment system monitoring will also include recording the flow totalizer readings on each pumping well, gaging of monitoring wells for depth to groundwater, and sampling of selected monitoring wells for VOC analysis. Each quarter, 10 key wells will be monitored to provide an indication of containment of the groundwater plume. These indicator wells include W-1, W-6, W-7, BR-308, OW-102, OW-304, OW-401, OW-404U, OW-404L, and OW-405. The groundwater samples will be analyzed on-site for pH and conductivity; and sent off-site to a Puerto Rico-certified laboratory for analysis of chlorinated VOCs using EPA Method 8010.

3.42 Maintenance

Maintenance items associated with the new carbon adsorber and monitoring equipment will be conducted by Terra Vac during start-up. Periodic maintenance on the currently existing equipment and systems will be continued by Circo plant personnel.

3.50 PERFORMANCE MONITORING

The actual performance of the groundwater containment system will be documented through water level and water quality monitoring. Water level measurements will be used to calculate drawdown in the vicinity of the pumping wells. Drawdown measurements will be used to assess hydraulic gradients, the combined areas of influence and associated capture zone.

Water quality data will be collected from the existing monitoring well network. At a minimum, water quality monitoring will include analysis for volatile organic compounds, including chlorinated ethenes. Analyses will be conducted under the direction of a Puerto Rico certified analytical chemist. The water quality data will be used to assess contaminant distribution and temporal contaminant fluctuations.

Specific performance monitoring locations will be evaluated during the system start-up. Based on the presently available information, including the conceptual groundwater containment system design, the following existing monitoring points will be included in the performance monitoring program.

Water Level Monitoring	All existing monitoring wells, observation wells, and bedrock water supply wells
Water Quality Monitoring	W-1, W-6, W-7, BR-308, OW-12, OW-304, OW-401, OW-404U, OW-404L and OW-405

After startup and shakedown, groundwater monitoring on a quarterly basis (4 times per year) will be performed for one year. Subsequently, an alternative monitoring frequency (such as semi-annual) in the years that follow may be proposed. Results of the performance monitoring will be transmitted to EQB with regular progress reports.

4.00 SVE SYSTEM

The soil vapor extraction (SVE) system is intended to remove VOCs from soils above the water table in the vicinity of the loading dock. The system will use three wells spaced approximately 20 feet apart along the north side of the loading dock, as shown on Figure 6. The extraction wells will be piped so they can also operate as air inlet wells. This will allow flexibility during system operation to vary the subsurface flow patterns, which may be necessary to reduce dead zones (i.e. locations where limited flow conditions exist) or to increase the influx of clean atmospheric air into the subsurface.

4.10 DESIGN

The rate of VOC removal for a system of this type depends on the spacing and placement of extraction wells, the magnitude of the vacuum applied at the extraction wells and the resulting air flow rate. The primary design bases for the soil vapor extraction system are:

1. the volume of soil requiring remediation;

2. the pneumatic conductivity of the soils to be remediated; and

3. the number of pore volume exchanges of air through the contaminated soils required to reach the Remedial Standards (see Section 2.00). This in turn depends on soil gradation, moisture and organic carbon content, and the initial and final VOC concentrations.

The plan view area of soils requiring remediation near the loading dock is about 50 feet by 40 feet constrained by the dimensions of the loading dock. The depth to the water table in this area is approximately 20 to 25 feet. Therefore, the volume of soil to be treated by SVE is approximately 46,000 cubic feet or 1,700 cubic yards (cy).

The soils in the vicinity of the proposed soil vapor extraction system consist primarily of clay and silt fill and natural residual silty clay (native soils) with estimated hydraulic conductivities typically ranging from $4x10^{-5}$ to $2x10^{-4}$ centimeters per second (cm/sec) or about 0.1 to 0.5 feet per day (ft/day). These estimates are based on field rising head tests and on laboratory grain size analyses.

The above hydraulic conductivities translate to theoretical pneumatic conductivities on the order of $3x10^{-6}$ cm/sec to $1x10^{-5}$ cm/sec, based on the differences in the properties of the fluids (i.e., air versus water). However, the actual pneumatic conductivities will

be lower than these estimates given that the soil pores are partially filled with water. The actual pneumatic conductivities are likely in the range of $5x10^{-7}$ cm/sec to 10^{-5} cm/sec.

Based on the particle size distributions observed in the laboratory for silty clay soil similar to that found under the loading dock area, the height of capillary saturation may exceed 10 feet. Therefore, much of the soil pore space may be occupied by water. For developing the conceptual design, we have assumed a pneumatic conductivity of $7x10^{-7}$ cm/sec (toward the low end of the estimated range given above).

Preliminary modelling indicates that an applied vacuum of 20-inch Hg will obtain a flow rate of 0.7 scfm per well, achieving a turnover of 1,000 pore volumes in four years. To achieve this vacuum, a positive-displacement air cooled rotary lobe blower will be used. These types of blowers can achieve vacuums of over 22-inch Hg, and require very low maintenance.

The air/water separator will be used to remove entrained water and condensation. The collected water will be pumped to the water treatment system. The air discharge of the separator tank will connect to the extraction blower. The discharge of the blower will exhaust to atmosphere, as vapor treatment is not anticipated to be required.

4.11 Extraction Well Layout

GZA assessed the performance of the proposed SVE system using a computer model based on the Theis equation. The model predicts extraction flow rates and subsurface vacuum distributions for a given applied vacuum. For three wells spaced approximately 20 feet apart, the model predicts an extraction flow rate of approximately 0.7 standard cubic feet per minute (SCFM) from each well at an applied vacuum of 20 inches of mercury (in. Hg). Approximately four years will be required to achieve 1,000 pore volume exchanges at this air flow rate, assuming an effective soil porosity of 10 percent (for air). Based on this analysis, it is believed that three extraction wells should be sufficient for remediation of the loading dock soils. The proposed location of each extraction well is shown on Figure 6.

4.12 Pumping and Piping Systems

Because of the low pneumatic conductivities in the soil under the loading dock, high vacuums (i.e., greater than 0.5 atmospheres) are likely required to keep the predicted remediation time to less than five years. A positive displacement, rotary-lobe vacuum pump can apply the necessary vacuums to the extraction wells. Applying a high vacuum will overcome capillary tensions in some of the soil pores, thus

providing a greater volume through which air can flow in the subsurface. An air-water separator will be required at the influent to the vacuum pump to remove water entrained in the air stream. The process flow diagram is shown in Figure 2.

The theoretical well operating conditions, as stated earlier, are 0.7 scfm per well at 20-inch Hg. However, local experience indicates that these soils can generally yield a greater flow than the theoretical predictions indicate. As such, the design air flow rate for the piping system has been increased to 5 scfm per well, or 15 scfm total; and the blower has been sized to provide over 15 scfm at 20-inch Hg.

The vacuum pump will be located near the loading dock. Because of the low anticipated flow rates, small diameter piping (i.e., 2-inch piping with 1-inch valves) will be used to connect the wells to the air/water separator at the inlet to the vacuum pump. Each well will have an individual line running to the equipment location with the sampling and control instrumentation located at the SVE system, thereby eliminating the need for routine access to the loading dock parking area. The piping will run below the ground surface from the well heads to the wall of the loading dock. The lines to each well will be fitted with a vacuum gauge and a flowmeter to monitor applied vacuums and resulting extraction flow rates. There will also be an on/off ball valve, a throttling valve and an air inlet valve on the extraction lines. An air makeup valve will be located between the pump and the air/water separator to regulate the vacuum in the vapor extraction piping. Effluent air from the pump will discharge to the atmosphere. Presently the need for air pollution controls to remove VOCs from the effluent air is not anticipated.

4.20 SYSTEM PERFORMANCE SPECIFICATIONS AND DESIGN CRITERIA

The SVE system has been designed to meet the following performance standards:

1. VOC Removal - The system will operate until VOC concentrations are below risk-based Media Protection Standards or other RMSs.

2. Remediation Timeframe - The well locations and vacuum action levels will be designed with the intent of achieving the desired VOC removal within a four-year timeframe.

To achieve these objectives, an SVE system that can apply a minimum 20" Hg vacuum to the extraction well heads is required. Based on previous modelling, a flow rate of 0.7 scfm per well at three wells will be required to achieve a sufficient number of pore volumes (1,000) in the target time frame of 4 years.

The system must meet federal air discharge requirements (less than 1 ton/year of VOCs). Based on available soil vapor concentration data showing a maximum of 200 ppmv of VOCs in the loading dock area soil gas, the SVE system is expected to initially extract approximately 0.27 pounds per day total VOCs. The initial extraction rate is expected to decrease rapidly.

The system should be low maintenance, capable of running unattended for up to one month at a time. The SVE system will have a method of notifying the operators of a system malfunction. Any entrained water and condensate will be automatically sent to the existing water treatment facility.

4.30 SYSTEM DESCRIPTION AND SPECIFICATIONS

The following sections detail the equipment specifications for the size and capacity of the SVE system components.

4.31 SVE Wells

As discussed in Section 3.10.1, three SVE wells will be installed in the vicinity of the loading dock. The SVE wells will be spaced approximately 20 feet apart. The SVE wells will be completed at a depth of approximately 18 feet below land surface (bls), with a screened interval from 3 to 18 feet bls. Screening the SVE wells at this interval will limit the quantity of groundwater entrained in the vapor stream. Figure 7 shows the SVE well design.

The SVE wells will be constructed of four inch schedule 40 PVC riser and well screen (.020 inch slotted). The wells will be placed in 6.5-inch-diameter auger drilled boreholes. The boreholes will be backfilled with 12 to 20 feet of filter sand and a seal at the surface.

4.32 SVE Manifold

The size of the SVE piping was chosen based on the following criteria:

- Design flow of 5 scfm per well
- Initial system of three SVE wells with the potential for system expansion
- Maximum piping run of 100 feet
- Installation compatibility with other system components

Based on the above criteria, 2 inch schedule 40 PVC pipe was selected for the SVE piping. Each well will have an individual line running to the SVE equipment

shed. Subsurface piping will be installed to a depth of at least 2 feet below grade, as shown in Figure 8.

4.33 Air/Water Separator

To limit free liquid drawn through the SVE blower, an air/water separator will be installed on the inlet side of the SVE blower. The air/water separator will be constructed of carbon steel. The body will be rolled and seam welded. The top and bottom heads will be pressed and welded to the vessel. The inside of the air/water separator will be epoxy-coated to limit rusting. Additional specifications for the air/water separator are as follows:

- Maximum anticipated operating flowrate of 25 scfm
- Minimum vacuum rating of 24" Hg
- Minimal liquid extraction anticipated
- Maximum velocity across impingement separation panels of 5 to 7 feet per second (fps)
- Retention capacity of 50 gallons
- Liquid level sight glass
- Internal impingement baffles
- 1.0 Hp close-coupled, self-priming, centrifugal, liquid transfer pump with automatic level controls, with a suction capacity of 26 inches Hg and a total head

Any water entrained during SVE operations will be pumped by the transfer pump to the existing 25,000-gallon equalization tank for treatment.

4.34 SVE Blower

The capacity of the SVE blower was based on the following design criteria:

- Nominal flow rate of 5 scfm per well from three SVE wells for a total of 15 scfm
- Nominal operating vacuum of 20" Hg
- Excess capacity for additional SVE wells

The SVE blower will be a 7.5 hp, positive-displacement, air-cooled rotary lobe blower capable of producing greater than 20" Hg vacuum and 20 scfm of air flow. The SVE blower will have the following features:

- V-belt drive with belt guard
- Inline inlet particulate filter
- Butyl inlet expansion joint
- EPDM discharge expansion joint
- Discharge silencer
- Motor slide base
- Dilution valve assembly (includes particulate filter and butterfly valve)
- NEMA 7 starter enclosure
- Inlet vacuum gage
- Discharge pressure gage
- Discharge temperature gage
- Inline inlet filter differential pressure gage

The blower will be housed in a sound insulated enclosure to limit noise levels outside of the enclosure to less than the 85 dB OSHA standard.

4.35 System Controls

The SVE blower will be controlled by a manual start-stop button on the motor starter cabinet. The water transfer pump will be controlled by a hand/auto/off switch on its motor starter box. In automatic, the pump will cycle based on the high and low level switches in the air/water separator.

A high level alarm switch in the air/water separator will shut the vacuum extraction blower down.

An autodialer will be provided which will alert the local Terra Vac office in case of a system shutdown or malfunction. These alarm conditions will include loss of power, high liquid level in the vapor/water separator, and blower shut-down.

4.40 O&M REQUIREMENTS

Following system construction, O&M for the system will be implemented. This will include preparation of an O&M manual, routine maintenance and monitoring, and system performance assessment.

After system startup and shake-down, an operations manual that will include recommended operating specifications, performance standards and monitoring, routine and preventative maintenance, and troubleshooting information will be developed. This manual will be submitted to Digital for review and approval, with the final edited version also submitted to Digital and Circo.

4.50 PERFORMANCE MONITORING

During the initial one-to-three month operating period, GZA and Terra Vac will evaluate the system performance using an enhanced monitoring schedule. The data gathered during this period will be use to optimize performance of the SVE system.

The performance of the SVE system will be assessed both at startup and periodically during system operation. Prior to startup, air samples will be collected from each well to assess initial VOC concentrations in soil vapor. To assess whether the wells have a sufficient capture radius, a vacuum will be applied to one well at a time while measuring resulting vacuums in the other wells. If no vacuums are observed in wells adjacent to the one to which a vacuum is applied, additional wells may need to be added as part of the Observational Method Contingency Planning.

During the first day of operation, air samples from the vacuum pump effluent will be collected several times to verify compliance with air discharge regulations. Air samples from the extraction lines connected to each well will also be analyzed to assess individual changes in VOC concentrations at each well.

For the portion of the first month of operations after the one week start-up period, site visits will be conducted weekly. During each visit, vapor samples will be taken from each extraction well and the blower exhaust and analyzed on-site using a field gas chromatograph with flame ionization detector (GC/FID) for evaluation of total VOCs and specification of individual compounds. A PID will also be used as a back-up quality check. SVE system monitoring will also include measurement of well and system vacuums and flows.

During the remainder of the first quarter, site visits will occur monthly. Monitoring will be conducted as described above for the weekly visits.

Following the first quarter, routine site visits and monitoring events will be conducted quarterly. Routine operations will include system cleaning and adjustments, routine and preventative maintenance, and repair of system components as required.

During routine operation, samples of the effluent air from the vacuum pump will be analyzed several times each year to assess the progress towards cleanup. When VOC

levels in the pump effluent air indicate that cleanup conditions have been achieved, the system will be shut off for a period of 72 hours. Air samples will then be collected from each well. If these air samples indicate that soil VOC levels are below the Remedial Standards (see Section 2.00), remediation will be considered complete. Otherwise the system will continue to operate until the Remedial Standards are achieved.

GZA

5.00 PROJECT SCHEDULE

Terra Vac's projected schedule for completion of this work is shown in Figure 9. The schedule was developed based on our present understanding of potentially applicable regulatory requirements. It represents Terra Vac's present estimate of an aggressive schedule that would result in startup of the remedial systems in the fourth quarter of 1995.

As necessary, revised schedules will be provided to Digital as the work progresses. The schedule allowances for each major step in implementing the Voluntary Interim Measure include:

Permitting - allowance for 12 weeks (three months) after completion of the design.

Construction - about 16 weeks (about four months) inclusive of equipment lead time and mobilization;

Operations and Maintenance - Based on the above, startup of the system in the fourth quarter of 1995 is anticipated. The period of operation will be dependent on remedy efficiency.

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TABLES

TABLE 1

PATHWAY - SPECIFIC CONCENTRATION LIMITS FOR SOIL

Receptor	Exposure Pathway	Contaminant	Risk-based PSCLs	
			10-6 (mg/kg)	HI = 1 (mg/kg)
Utility Worker	Dermal Contact and Incidental Ingestion of Soil	Trichloroethene	21,800	
	Dermal Contact and Incidental Ingestion of Soil	cis 1,2-Dichloroethene trans 1,2-Dichloroethene		171,000 342,500

TABLE 2

PATHWAY - SPECIFIC CONCENTRATION LIMITS FOR GROUNDWATER

Receptor	Exposure Pathway	Contaminant	Risk-based PSCLs		AWQC-based PSCLs
			10-6 (ug/l)	HI = 1 (ug/l)	(ug/l)
			Overburden	Overburden	
Utility Worker	Dermal Contact with Groundwater	Chloroform	40,000	17,000	
		cis 1,2-Dichloroethene		3,500,000	
		1,2-Dichloroethane	50,000		
		Trichloroethene	11,000		
		1,1-Dichloroethane		29,000,000	
		1,1-Dichloroethene	2,500	97,000	
			Bedrock	Bedrock	
Facility Worker	Inhalation of Indoor Air	cis 1,2-Dichloroethene		8,700	
		Trichloroethene	26	1,400	
					Overburden
Local Residents; Freshwater Aquatic Life	Fish Consumption: Bioaccumulation/Uptake	1,1-Dichloroethane			201,000,000
		1,1-Dichloroethene			23,000
		1,2-Dichloroethane			25,000,000
		Chloroform			1,500,000
		cis 1,2-Dichloroethene			14,600,000
		trans 1,2-Dichloroethene			14,600,000
		Methylene Chloride			157,500,000
		Tetrachloroethene			111,000
		Trichloroethene			1,000,000
					Bedrock
		1,1-Dichloroethane			30,600,000
		1,1-Dichloroethene			3,500
		1,2-Dichloroethane			3,800,000
		Chloroform			237,000
		cis 1,2-Dichloroethene			2,200,000
		trans 1,2-Dichloroethene			2,200,000
		Methylene Chloride			24,000,000
		Tetrachloroethene			17,000
		Trichloroethene			154,000

FIGURES

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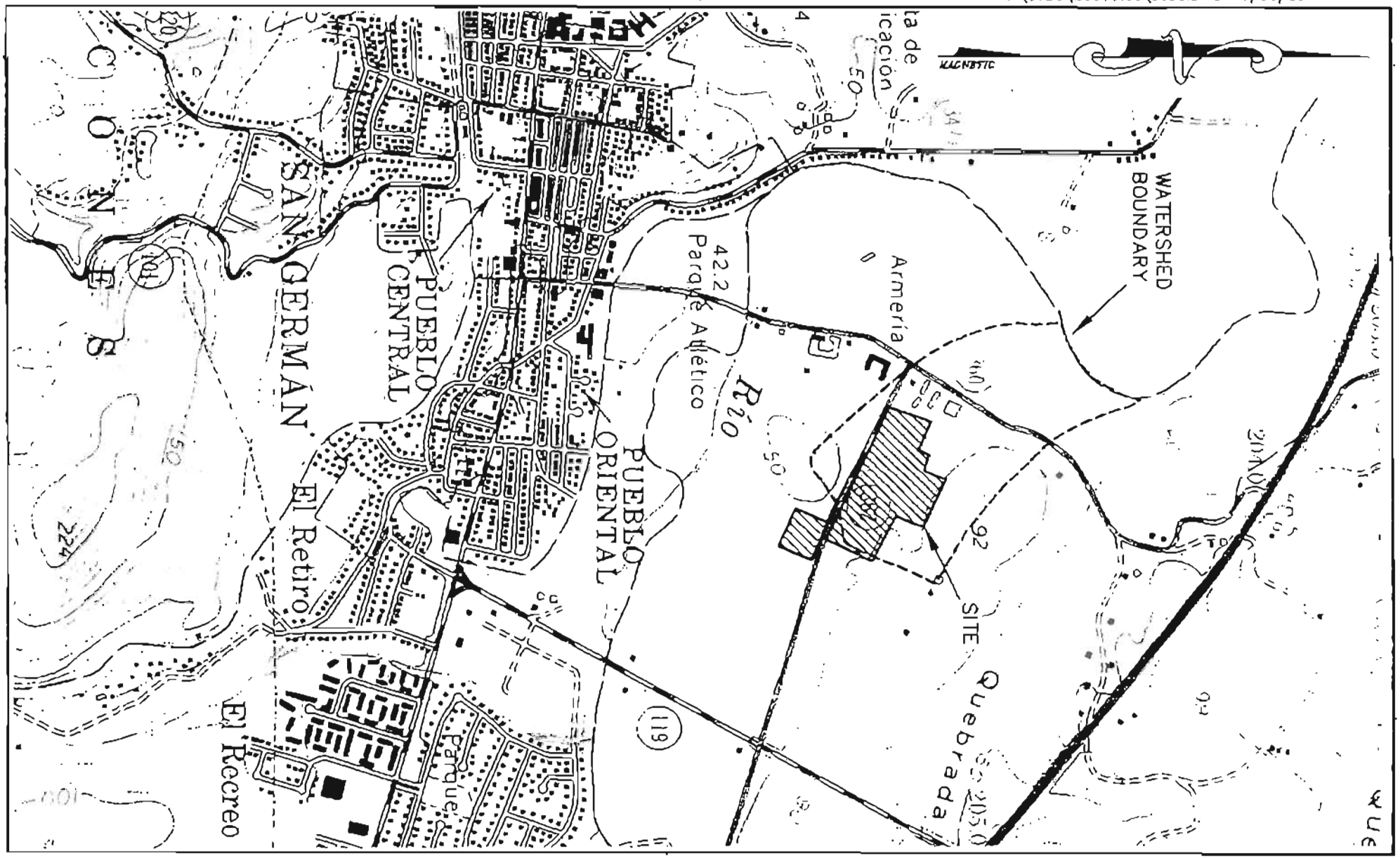
FILE INFO: C:\JOBS\20876.12\FIG1.DWG 7/31/96



REMEDIAL SYSTEMS DESIGN REPORT
DIGITAL EQUIPMENT CORP.
SAN GERMAN, PUERTO RICO

LOCUS PLAN

PROJECT No.: 20876.12
FIGURE No.: 1

DES'D BY	: JRP
CHK'D BY	: JRP
APP'D BY	: MJB
DRAWN BY	: DRE
SCALE	: 1"=1000'
DATE	: JULY 95

GRAPHIC SCALE
1000' 0' 1000' 2000'

GZA GeoEnvironmental, Inc.
Engineers and Scientists
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PORTLAND, MAINE 04101
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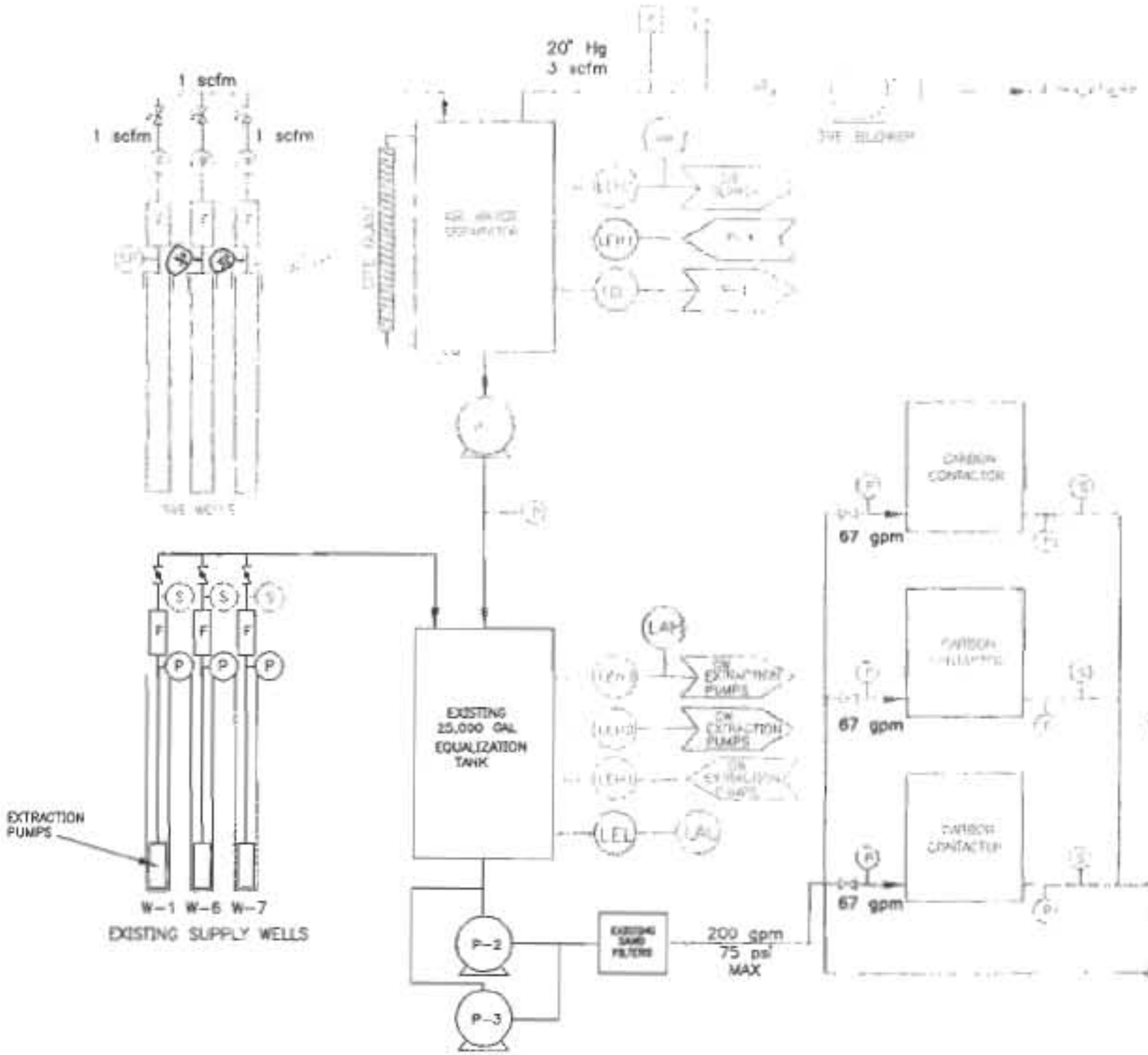

LEGEND:

- P — PRESSURE GAGE
- F — FLOW METER
- BALL VALVE
- BUTTERFLY VALVE
- CHECK VALVE
- S — SAMPLING PORT
- S-1 — SOLENOID VALVE (NORMALLY CLOSED)
- V — VACUUM GAGE
- SVE BLOWER — AUTOMATIC SHUT-OFF
- P-1 — AUTOMATIC START
- LAH — LEVEL ALARM HIGH
- LAL — LEVEL ALARM LOW
- LEH — LEVEL ELEMENT HIGH
- LEL — LEVEL ELEMENT LOW

DESIGN ASSUMPTIONS

- Existing water production wells W-1, W-6 and W-7, and the rest of the existing extraction/treatment system are in good working condition and will be maintained by Circo.
- The existing flow valves will be used to balance the relative flows of W-1 and W-6 to enhance containment effectiveness.
- The required peak process flow from the groundwater treatment system is 200 gpm, based on conversations with Circo.
- The maximum system pressure at the inlet to the new carbon vessels is no more than 75 psig.
- Water production wells W-3, W-4 and W-5, as wells as any other wells upgradient and/or cross-gradient of the facility will no longer be used.
- While intermittent production well use is not inconsistent with effective groundwater containment, an average monthly groundwater extraction rate of at least 40 gpm will be maintained.
- The existing carbon vessels, when connected in parallel, can withstand the pressures and flows of the full production capacity.
- The existing pressure demand pumps can accept the added head loss associated with the new carbon contactors.
- The existing, redundant municipal water supply capacity is capable of, and will be used to, supply Circo's process water needs during periods of malfunction or maintenance of the groundwater extraction/treatment system components.
- Electrical power of 3-phase, 230-volt, 30 amps for the vacuum extraction blower is available near the proposed SVE shed location.
- The SVE system influent VOC concentration will not exceed the highest soil gas concentration seen to date in the loading dock area (220 ppm), and thus VOC emission rates will not exceed the EQB limits of 3 pounds per hour or 15 pounds per day. Therefore, air controls will not be required.

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NOTE:

1. ITEMS SHOWN IN BLACK ARE EXISTING EQUIPMENT AND ITEMS SHOWN IN RED ARE TO BE ADDED.

REV. NO.	DESCRIPTION	BY	DATE
	Final Draft		8-16-95

PROJ MGR: JRP
DESIGNED BY: DEO (T.V.)
REVIEWED BY: MJB
DRAWN BY: DTH
DATE: 7/20/95

GeoEnvironmental, Inc.

TERRA VAC

PROCESS AND INSTRUMENTATION DIAGRAM

FORMER DIGITAL FACILITY
SAN GERMAN, PUERTO RICO

PROJ NO: 20678.12
SCALE: N.T.S

FIGURE 2

25613P02
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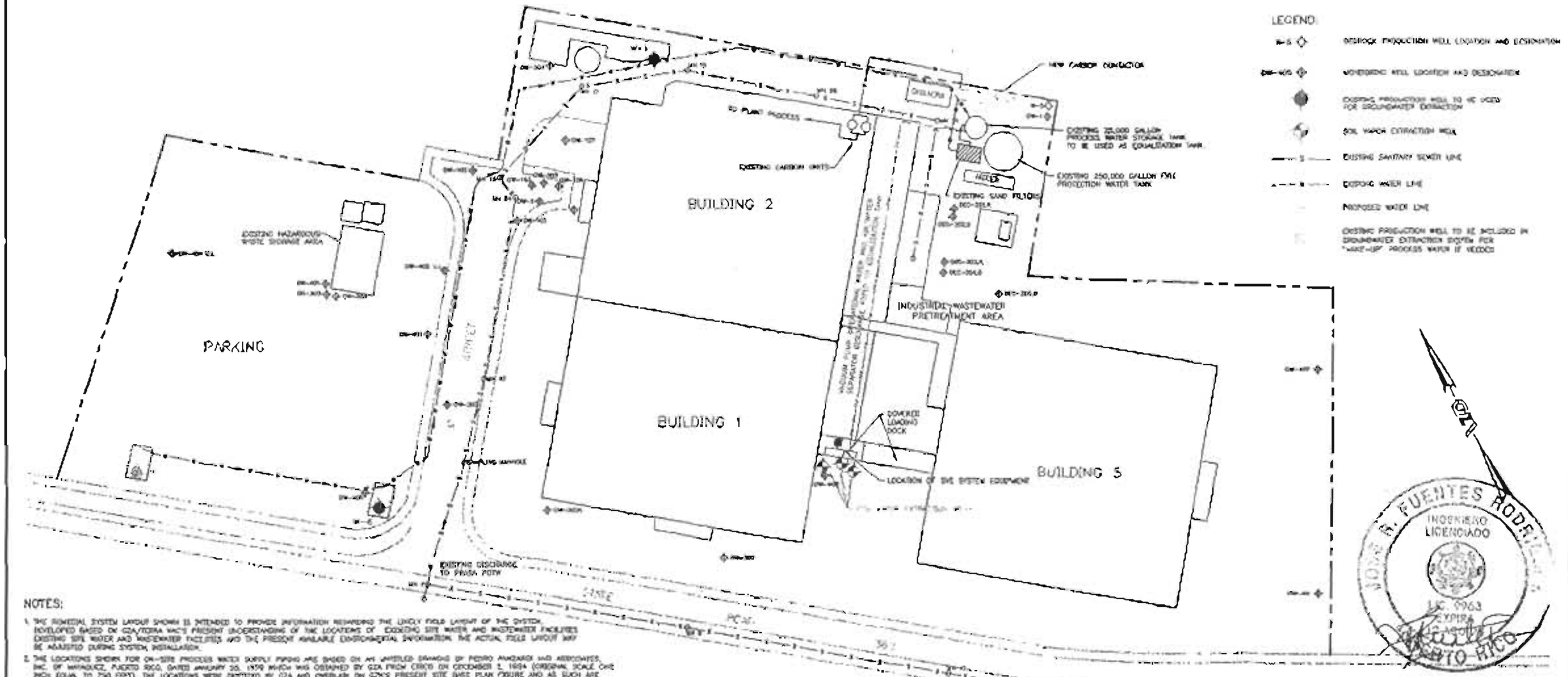

NOTES:

1. THE REMEDIAL SYSTEM LAYOUT SHOWN IS INTENDED TO PROVIDE INFORMATION REGARDING THE LIKELY FIELD LAYOUT OF THE SYSTEM. DEVELOPED BASED ON GZA/TERRA VAC'S PRESENT UNDERSTANDING OF THE LOCATIONS OF EXISTING SITE WATER AND WASTEWATER FACILITIES. EXISTING SITE WATER AND WASTEWATER FACILITIES AND THE PRESENT AVAILABLE ENVIRONMENTAL INFORMATION. THE ACTUAL FIELD LAYOUT MAY BE ADJUSTED DURING SYSTEM INSTALLATION.
2. THE LOCATIONS SHOWN FOR ON-SITE PROCESS WATER SUPPLY PIPING ARE BASED ON AN UNTITLED DRAWING BY PEDRO PANZARDE AND ASSOCIATES, INC. OF MAYAGUEZ, PUERTO RICO, DATED JANUARY 30, 1979 WHICH WAS OBTAINED BY GZA FROM CERCO ON DECEMBER 2, 1994 (ORIGINAL SCALE ONE INCH EQUAL TO 750 FEET). THE LOCATIONS WERE DIGITIZED BY GZA AND OVERLAIN ON GZA'S PRESENT SITE BASE PLAN FIGURE AND AS SUCH ARE APPROXIMATE AND NOT INTENDED FOR FINAL DESIGN PURPOSES.
3. THE LOCATIONS SHOWN FOR ON-SITE WASTEWATER SYSTEM COMPONENTS ARE BASED ON SHEETS 2 AND 3 OF A SET OF 1992 DRAWINGS BY PEDRO PANZARDE ASSOCIATES, INC. OF MAYAGUEZ, PUERTO RICO ENTITLED "DIGITAL EQUIPMENT CORPORATION, SAMPLING EQUIPMENT MODIFICATION, STATE ROAD NO. 343, SAN GERMAN, PUERTO RICO." THE LOCATIONS WERE DIGITIZED BY GZA AND OVERLAIN ON GZA'S PRESENT SITE BASE PLAN AND AS SUCH ARE APPROXIMATE AND NOT INTENDED FOR FINAL DESIGN PURPOSES.
4. THE BASE PLAN WAS DEVELOPED FROM THE FOLLOWING SOURCES:
   - A PLAN PROVIDED BY PEDRO PANZARDE & ASSOCIATES OF MAYAGUEZ, PUERTO RICO, ENTITLED, "SITE PLAN W/LOCATIONS OF SEWER SYSTEM, SHEET NO. 3 OF 7 PROJECT NO. 9511, DWG. NO. S-1.1, DATED 2/1/88, ORIGINAL SCALE: 1:500 OR 1"=41'"
   - A PLAN PROVIDED BY DIGITAL EQUIPMENT CORPORATION (DEC), SAN GERMAN, PUERTO RICO, ENTITLED, "PLAN & PROFILE" DRAWN BY VELAZQUEZ, DATED 1/23/87, ORIGINAL SCALE OF SITE PLAN: 1:500 OR 1"=41'"
   - THE YARD FEATURES WERE BASED UPON A PLAN ENTITLED, "BLOW UP OF NEW FACILITIES", SHEET 6 OF 7, PREPARED BY PEDRO PANZARDE & ASSOCIATES OF MAYAGUEZ, PUERTO RICO, DATED 1/20/89, ORIGINAL SCALE: 1:200.
   - THE INTERIOR BUILDING LAYOUT, ROOM NAMES AND INDIVIDUAL ROOM OR YARD DETAILS ARE BASED UPON COMPUTER-GENERATED DRAWING FILES PROVIDED BY DIGITAL EQUIPMENT CORPORATION OF SAN GERMAN, PUERTO RICO. THE ITEMS SHOWN ON THE INDIVIDUAL ROOM OR YARD DETAIL AREA PLANS WERE NOT MODIFIED BY GZA. NOTES OR ADDITIONAL DETAIL INFORMATION WAS ADDED BY GZA TO CLARIFY ITEMS OR NAMES SHOWN.
5. THE LOCATIONS OF TEST BORINGS/WELLS WERE DETERMINED BY TAPE MEASUREMENTS AND "LINE-OF-SIGHT" OBSERVATIONS FROM EXISTING SITE FEATURES. THESE DATA SHOULD BE CONSIDERED ACCURATE ONLY TO THE DEGREE IMPLIED BY THE METHOD USED.

REV. NO.	DESCRIPTION	BY	DATE
	Final Draft		8/6/95

PROJ MGR: JRP
DESIGNED BY: DEO (T.V.)
REVIEWED BY: MJB
DRAWN BY: DTH
DATE: 7/20/95

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TERRA VAC

SITE LAYOUT

FORMER DIGITAL FACILITY
SAN GERMAN, PUERTO RICO

PROJ NO: 20876.12
SCALE: 1" = 100'

FIGURE 3

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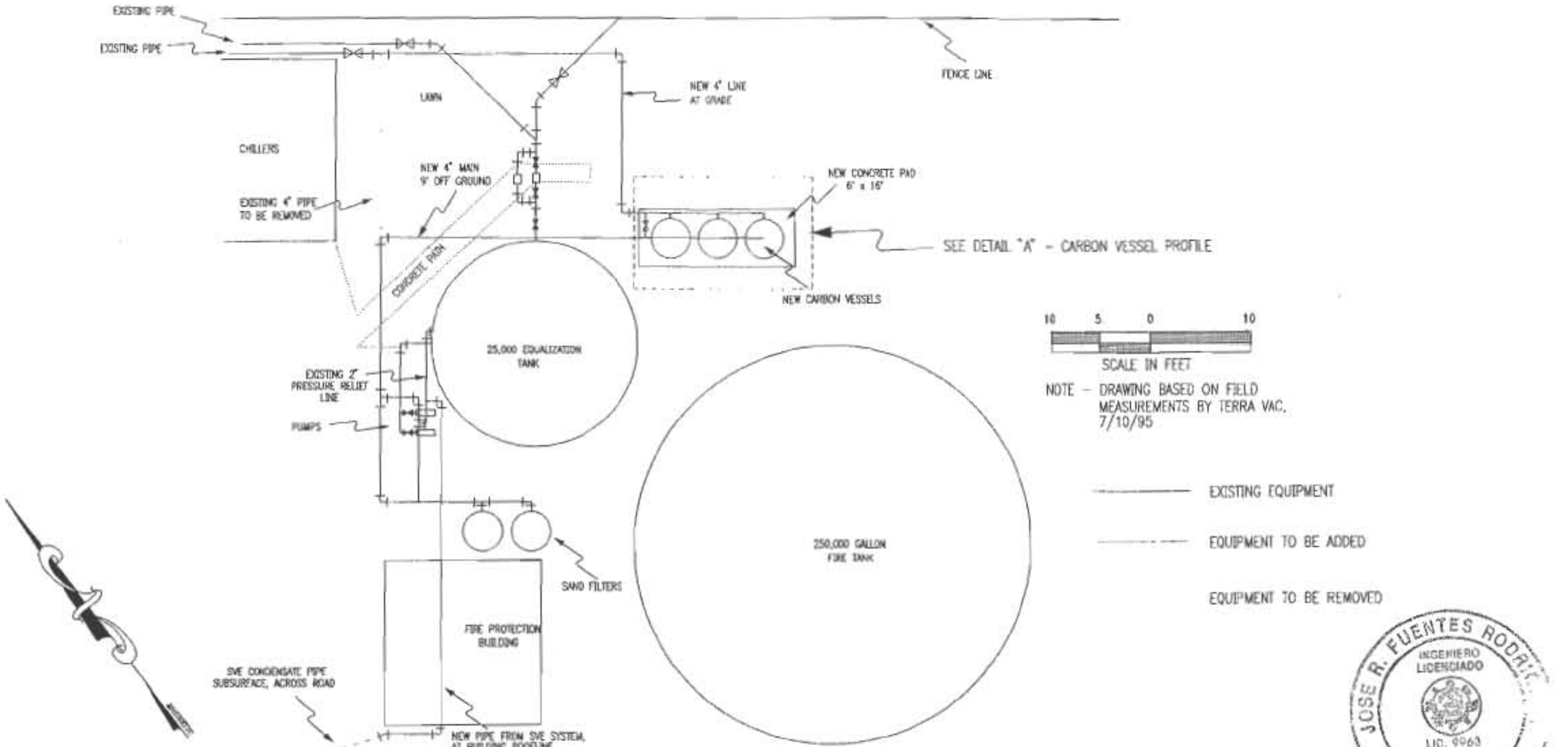
LIC. 9963
EXPIRA
PUERTO RICO



NOTE – DRAWING BASED ON FIELD MEASUREMENTS BY TERRA VAC, 7/10/95

——— EXISTING EQUIPMENT

– – – – EQUIPMENT TO BE ADDED

EQUIPMENT TO BE REMOVED

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REV. NO.	DESCRIPTION	BY	DATE
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DESIGNED BY: DEO (T.V.)
REVIEWED BY: MJB
DRAWN BY: DTH
DATE: 7/20/95

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TERRA VAC

CARBON LAYOUT/PIPING

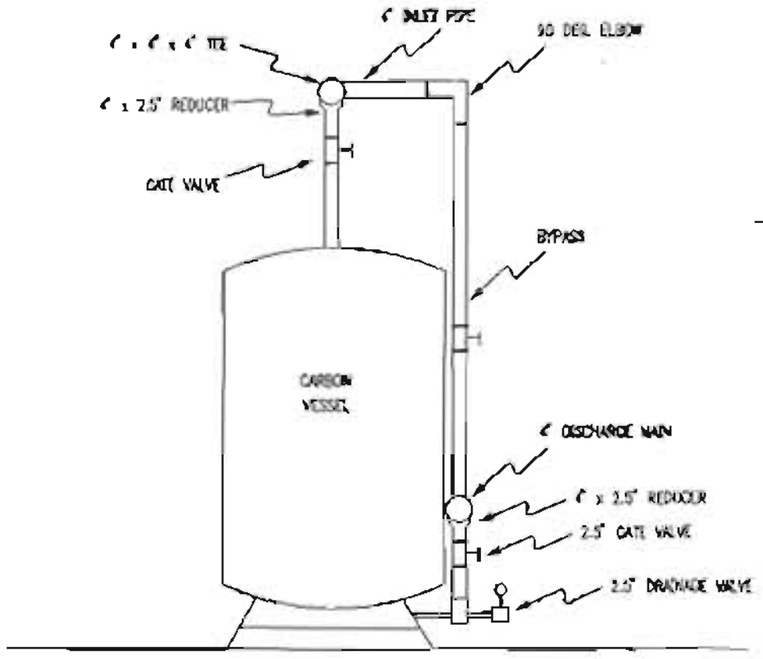
FORMER DIGITAL FACILITY
SAN GERMAN, PUERTO RICO

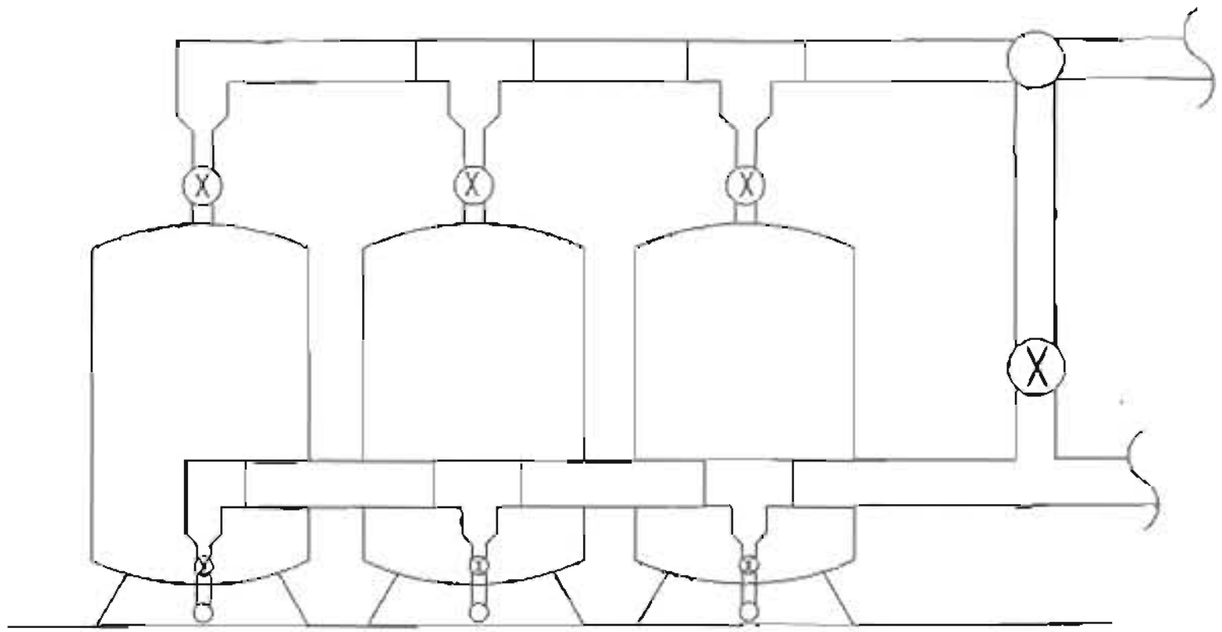
PROJ NO: 20878.12
SCALE: AS SHOWN

FIGURE 4

J.P. 8/17/1995, 15:40:35

END VIEW





SIDE VIEW

1 1/2 0 1

SCALE IN FEET

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REVIEWED BY: MJB
DRAWN BY: DTH
DATE: 7/20/95

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TERRA VAC

DETAIL "A"
CARBON VESSEL PROFILE

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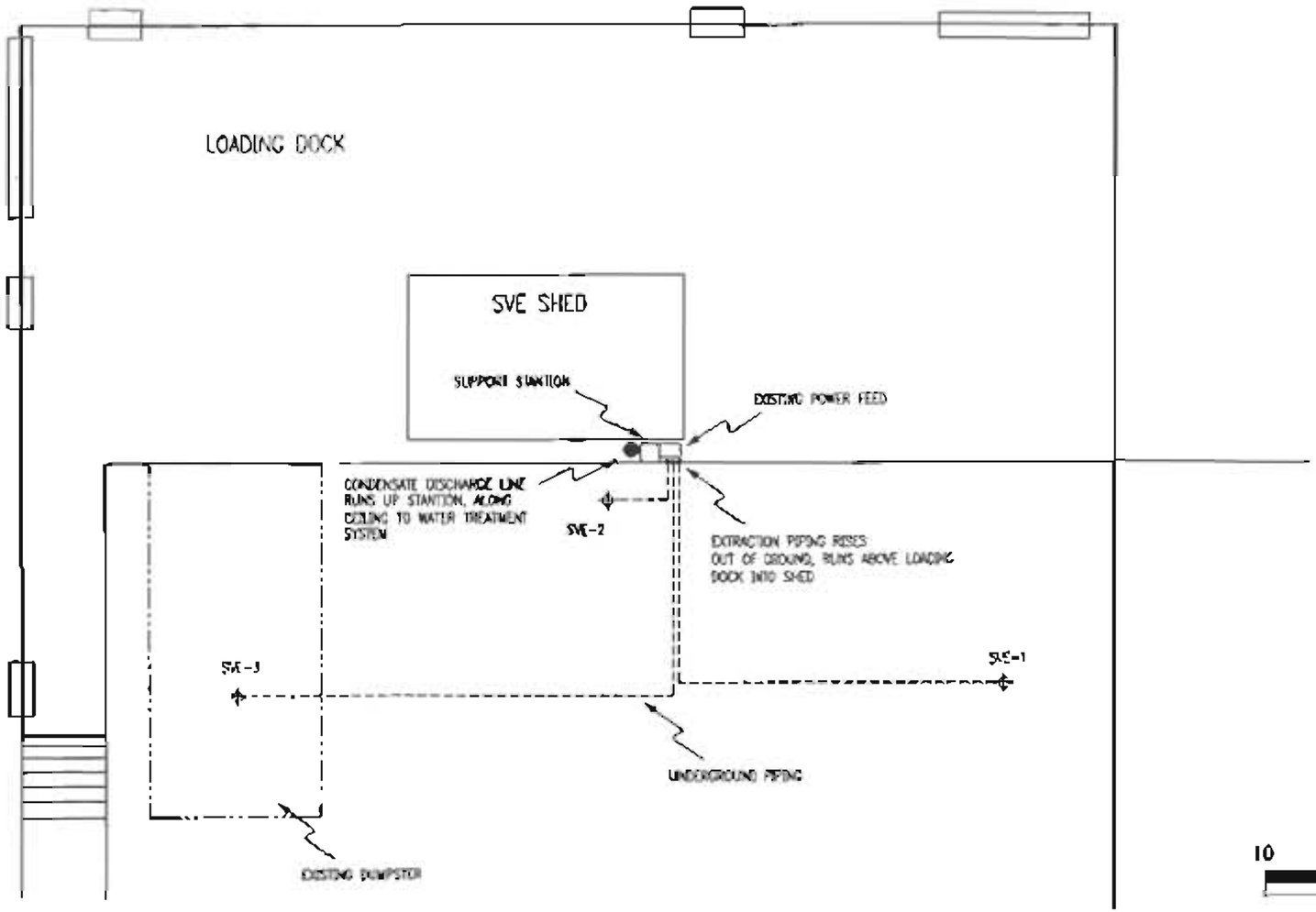
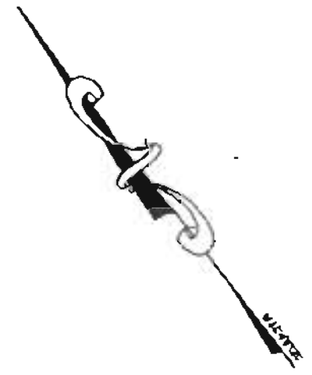
PROJ NO: 20878.12
SCALE: N.T.S.

FIGURE 5

AP: 8/17/1995, 10:27:06





10 5 0 10

SCALE IN FEET

SCALE BASED ON EXISTING SITE PLAN – FIGURE 2

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DESIGNED BY: DEO (T.V.)
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DRAWN BY: DTH
DATE: 7/20/95

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TERRA VAC

SVE EQUIPMENT LOCATION

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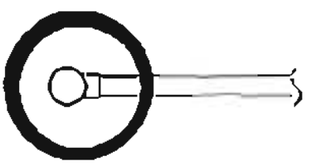
BAN GERMAN, PUERTO RICO

PROJ NO: 20675.12
SCALE: N.T.S.

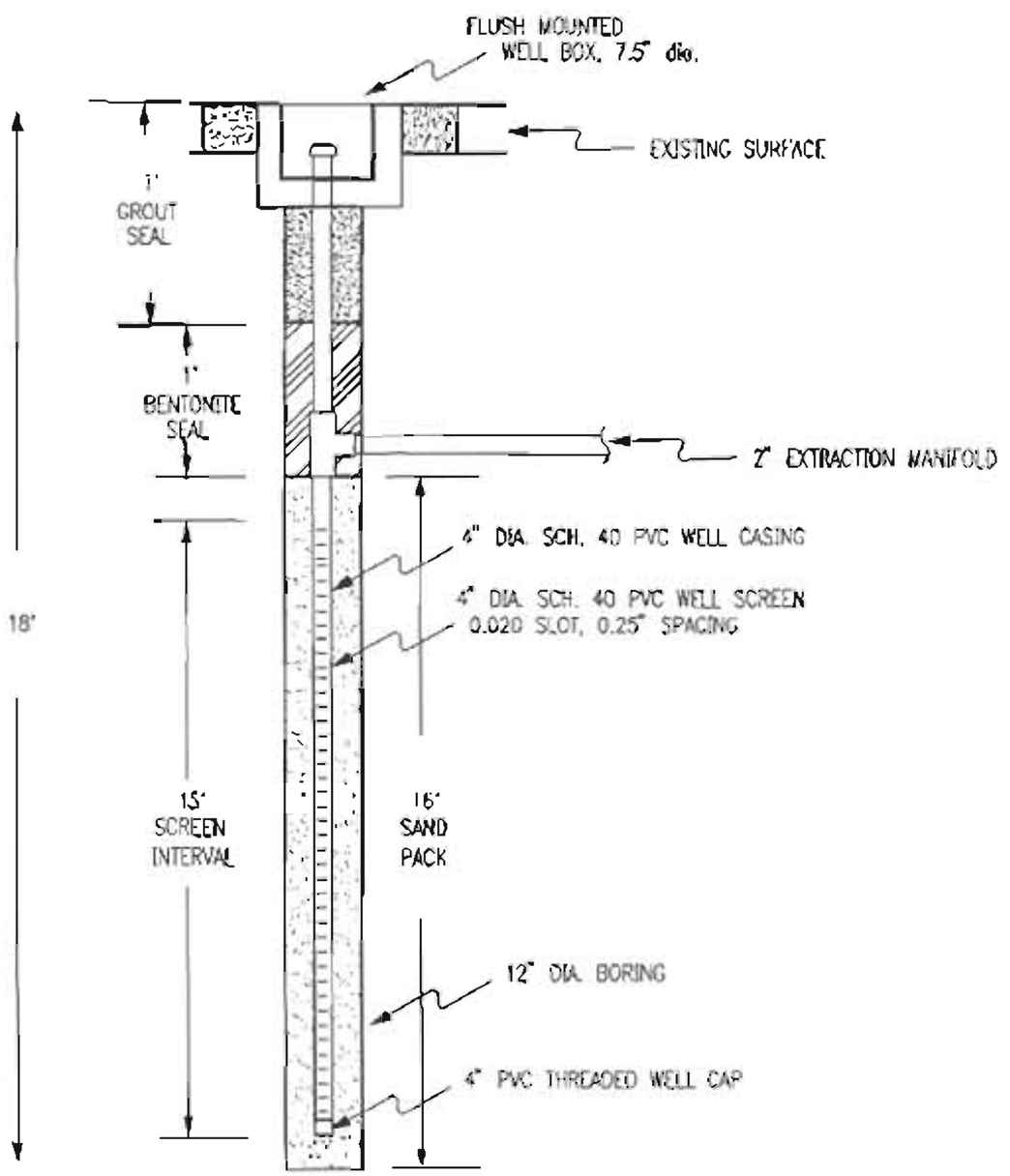
FIGURE 6

JRF, 8/7/1995, 15:50:20

TOP VIEW



SIDE VIEW



LEGEND:

GROUT

BENTONITE

#2-12 MONTEREY SAND

REV. NO.	DESCRIPTION	BY	DATE
	Final Draft		8-11-95

PROJ MGR: JAP
DESIGNED BY: DEO (T.V.)
REVIEWED BY: MJB
DRAWN BY: GTH
DATE: 7/20/95

GeoEnvironmental, Inc.

TERRA VAC

SVE WELL DESIGN

FORMER DIGITAL FACILITY
SAN GERMAN, PUERTO RICO

PROJ NO: 2009.12
SCALE: N.T.S.

FIGURE 7

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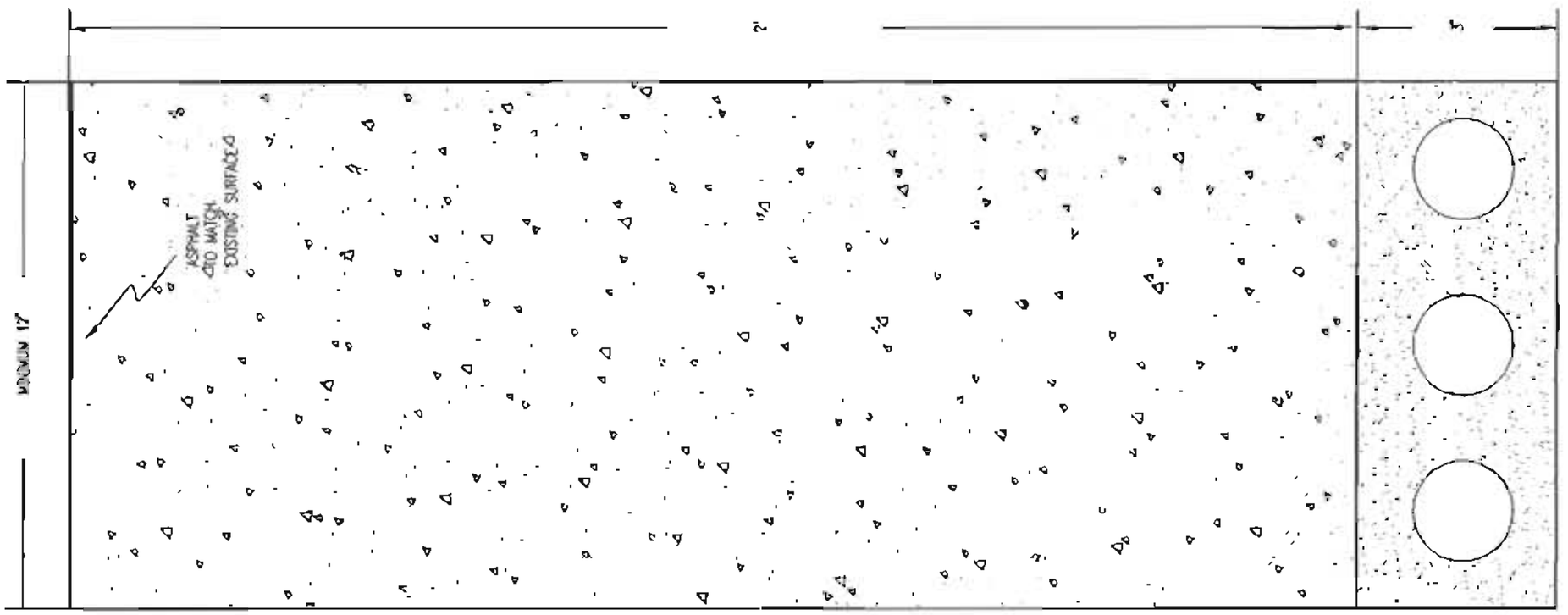
EXPIRA 12-31-96



JOSE R. FUENTES RODRIGUEZ
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LIC. 9963
EXPIRA 12 AGO 98
PUERTO RICO

REV. NO	DESCRIPTION	BY	DATE
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TERRA VAC

SVE TRENCH CROSS SECTION

FORMER DIGITAL FACILITY
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PROJ NO: 206/8.12
SCALE: N.T.S

FIGURE 8

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FIGURE 9
PROJECTED SCHEDULE

ID	Task Name	Duration	Start	Finish
1	2.0 DESIGN CONTRACTING	43d	5/1/95	6/30/95
2	3.0 DETAILED STUDIES AND DESIGN	92d	6/23/95	9/1/95
3	3.1 PRE DESIGN STUDIES	53d	6/23/95	7/14/95
12	3.2 MODIFIED DESIGN SUBMITTAL	32d	8/2/95	9/1/95
13	4.0 PERMITTING	89d	7/21/95	9/1/95
14	4.1 PRHWR Water Franchise Permitting	20d	7/21/95	8/17/95
15	4.2 PRASA Wastewater Discharge Perm	20d	7/21/95	8/17/95
16	4.3 Air Discharge Permitting	20d	7/21/95	8/17/95
17	4.4 Building/Local Permits	20d	7/21/95	8/17/95
18	5.0 CONSTRUCTION	80d	8/18/95	10/31/95
19	5.1 Preliminary Construction Activities	10d	8/18/95	8/31/95
20	5.2 Equipment Procurement	35d	8/18/95	10/3/95
28	5.3 Fabrication, Mobilization, Installation	30d	9/1/95	10/13/95
40	5.4 Startup	20d	9/25/95	10/31/95
41	7.0 OPERATIONS AND MAINTENANCE	266d	11/1/95	11/1/96
42	8.0 PROGRESS REPORTING/MEETINGS	365d	2/1/95	3/1/97
43	8.1 Meetings	371d	2/1/95	12/31/96
44	8.11 Quarterly Dig/Ker/EQB Meetings	327d	2/1/95	11/1/96
51	8.12 Monthly Meetings	371d	2/1/95	12/31/96
52	8.2 Progress Reports	369d	2/1/95	3/1/97
53	8.21 Quarterly EQB Progress Report	327d	2/1/95	3/1/97
60	8.31 Monthly Progress Reports	371d	2/1/95	12/31/96
66	8.31 Quarterly Insurance Statement	369d	2/1/95	3/1/97

APPENDIX A

NUMERICAL OPTIMIZATION PROGRAM FOR LEAST SQUARES FIT OF FIRST ORDER EXPONENTIAL DECAY EQUATIONS

APPENDIX A

NUMERICAL OPTIMIZATION PROGRAM FOR LEAST SQUARES FIT OF FIRST ORDER EXPONENTIAL DECAY EQUATIONS

This program estimates the optimum least squares fit of a first order exponential decay equation in the form:

$$C(i) = ((Co-Cf)\exp(k*t(i))) + Cf + e_1(i) \quad \ldots\ldots\ldots (1)$$

where:
- C(i) = Concentration at time t(i)
- t(i) = Time of occurrence for the i^{th} data set
- Co = Initial value at time t = 0
- Cf = Lower asymptote (C(i)=Cf when t(i)=infinity)
- k = Rate constant/unit time
- $e_1(i)$ = The residual error term for the i^{th} data set

Due to the nonlinear nature of this equation, linear least squares regression procedures cannot be directly implemented. However, by subtracting Cf from both sides of equation (1) and taking the natural logarithm of both sides, a linear approximation can be obtained resulting in the following equation

$$\ln(C(i)-Cf) = \ln(Co-Cf) + k*t(i) + e_2(i) \quad \ldots\ldots\ldots (2)$$

where: $e_2(i)$ = the residual error term for the i^{th} data set, and is not necessarily equal to $e_1(i)$.

In this form, the parameters Co, Cf, and k can be approximated using linear least squares regression procedures. However, equation (2) is not the same as equation (1) in as much as the form of the residual error term is different; that is, $e_1(i)$ is not equivalent to $e_2(i)$. Fitting equation (2) instead of equation (1) minimizes the sum of the square deviations in logarithmic space, but not in real space, thus biasing the parameter estimates in real space. One way to minimize this approximation error is to collect the data based on an exponential sampling frequency. However, this is often impractical and/or for various reasons undesirable. Therefore, a program was written to obtain an optimal least squares fit in real space.

The algorithm developed (see Attachment A) consists of three primary functions: (1) a procedure for obtaining initial parameter estimates to initiate the optimization process; (2) an iterative routine for selecting the optimal solution direction based on a least squares fit in real space; and (3) a mathematical routine for calculating the correlation coefficient for each iterative solution for assessment of the overall model performance. A brief discussion of these three primary functions is presented below:

CALCULATING INITIAL PARAMETER ESTIMATES

To obtain initial estimates of the three "fitting parameters" (i.e. Co, Cf and k), equation (2) was first fit utilizing linear least squares regression procedures. To limit the biases inherent in using linear regression techniques for solving exponential problems, the program uses the portion of the data set representing the initial rapid change in the y-axis parameter (upper limb) to obtain the initial estimate of Co and k, and the entire data set to obtain the initial estimate of Cf. This separation technique reduces the solution time needed by the iterative optimization routine; that is, it selects a better initial guess than would normally be obtained by performing a linear regression on all of the data for all three parameters at once (given that the subject data set was established based on a linear rather than exponential sampling frequency).

The procedure for selecting the portion of the data set to be used in calculating the initial values of Co and K is based on a percentage of the maximum change in concentration (i.e. the y-axis parameter) observed in the data set. The program first calculates the maximum concentration drop observed across the data set and then selects those data points which are represented in the initial 90% of that drop.

Once the two data sets are selected (i.e. (1) the data subset to estimate Co and k and (2) the entire data set to estimate Cf), a linear least squares regression was performed on each data set based on the following minimization equation:

$$Min\sum_{1}^{n}(e_2(i))^2=Min\sum_{1}^{n}((\ln(C(i)-Cf)-(\ln(Co-Cf)+k*t(i)))^2 \quad \ldots\ldots\ldots (3)$$

where: n = the number of data points.

By assuming a value of Cf, the partial derivative of the right-hand side of equation (3) with respect to Co and k can be taken and set to zero, and the parameter estimates of Co and k can then be obtained by reducing the two simultaneous equations to:

$$k=\frac{n\sum_{1}^{n}\ln((C(i)-Cf)*t(i))-(\sum_{1}^{n}\ln(C(i)-Cf))*(\sum_{1}^{n}t(i))}{n\sum_{1}^{n}t(i)^2-(\sum_{1}^{n}t(i))^2} \quad \ldots\ldots\ldots (4)$$

$$Co=\exp\left(\frac{\sum_{1}^{n}\ln(C(i)-Cf)-k\sum_{1}^{n}t(i)}{n}\right)+Cf \quad \ldots\ldots\ldots (5)$$

The lower asymptote of the exponential decay curve, Cf, was iterated from 99.99% of the minimum concentration to 0.0 in steps of 10% of the minimum concentration. For each value of Cf, the parameters Co and k were estimated, and the sum of the square residuals in real space was calculated by the following equation:

$$Min\sum_{1}^{n}(e_1(i))^2 = Min\sum_{1}^{n}(C(i)-(((Co-Cf)\exp(k*t(i)))+Cf))^2 \quad \ldots\ldots\ldots (6)$$

The initial values selected were the set of parameters corresponding to the Cf iteration which gave of smallest value of equation (5). This procedure was repeated using both data sets to obtain initial estimates of Co, k, and Cf.

ITERATIVE OPTIMIZATION ROUTINE IN REAL SPACE

To optimize the initial parameter estimates calculated above, an iterative routine was developed which searches for the optimal solution direction based on a step function related to the initial parameter values. At each iteration step, each parameter can be iterated in one of three fashions: (1) increase, (2) decrease, or (3) constant. Thus, for each iteration loop there were 27 different possible iteration scenarios. This in turn represented 26 possible changes in the sum of the square deviations in real space (one of the 27 scenarios corresponds to all values remaining constant).

Initially, the increase or decrease magnitude for the parameters was set to 10% of the initial value. At each of the 26 possible combinations, the sum of the square deviations (in real space) was calculated by equation (6). The scenario yielding the minimum sum of the square deviations, the least squares estimate, was then selected as the optimal solution direction, and the corresponding set of parameters were adopted as the current best set and used as the initial values in the next iteration. The iteration loop then began again using the same iteration step. If none of the combinations reduced the sum of the square deviations below the value given by the initial parameters, then the iteration step was reduced by a tenth of the previous iteration step. This procedure was continued until the iteration step for each parameter was 0.1% of the initial parameter value.

ASSESSING MODEL PERFORMANCE

At each new initial value of the parameters, the correlation coefficient between the inputted and predicted concentrations was calculated to assess the performance of the model. The predicted values were calculated via the following equation:

$$Pred(C(i)) = \{(Co-Cf)\exp(k*t(i))\} + Cf \quad \ldots\ldots\ldots (7)$$

The correlation coefficient between the inputted and predicted data sets was then calculated via the following equation:

.....(8)

$$Corr = \frac{n\sum_{1}^{n}(Pred(C(i))*C(i)) - (\sum_{1}^{n} Pred(C(i)) * \sum_{1}^{n} C(i))}{\sqrt{n\sum_{1}^{n}(C(i)^2) - (\sum_{1}^{n} C(i))^2} * \sqrt{n\sum_{1}^{n}(Pred(C(i))^2 - (\sum_{1}^{n} Pred(C(i)))^2}}$$

```
C-------------------------------------------------------------C
C  THIS PROGRAM INPUTS A DATA FILE OF CONCENTRATIONS AND TIME  C
C  AND FITS A NONLINEAR EXPONENTIAL CURVE TO THE DATA IN THE   C
C  FORM:                                                       C
C              C(i)=(Cf-Co)exp(kt(i)) + Co + e(i)              C
C                                                              C
C  THE CORRELATION COEFFICIENT BETWEEN THE ACTUAL AND THE      C
C  PREDICTED CONCENTRATIONS IS DETERMINED                      C
C-------------------------------------------------------------C

C  INTIALIZE ARRAY PARAMETERS

      DIMENSION CDEL(3),ICDEL(3),ACDEL(2)
      CHARACTER*20 INPUT(1),OUTPUT(1)

      COMMON /TIME/T(30)
      COMMON /CONC/C(30)

C  INTIALIZE STEP FUNCTIONS

      CDEL(1)=0.0
      CDEL(2)=0.1
      CDEL(3)=-0.1

C  INPUT FROM TERMINAL NAME OF INPUT AND OUTPUT FILES

      WRITE(*,*)'WRITE NAME OF INPUT FILE [IN QUOTES]: '
      READ(*,*)INPUT(1)
      WRITE(*,*)'WRITE NAME OF OUTPUT FILE [IN QUOTES]: '
      READ(*,*)OUTPUT(1)

C  OPEN INPUT AND OUTPUT FILES

      OPEN(7,FILE=INPUT(1))
      OPEN(8,FILE=OUTPUT(1))

C  INTIALIZE MINIMUM AND MAXIMUM CONCENTRATIONS

      CMIN=100000000.
      CMAX=0.0

C  READ CONCENTRATIONS AND TIME FROM INPUT FILE AND
C  DETERMINE MAXIMUM AND MINIMUM CONCENTRATIONS

      DO 10 I=1,1000

         READ(7,5,END=20)C(I),T(I)
    5    FORMAT(F6.1,2X,F6.1)

         IF(C(I).LT.CMIN)CMIN=C(I)
         IF(C(I).GT.CMAX)CMAX=C(I)

   10    CONTINUE
```

```
C  CLOSE INPUT FILE

   20 CLOSE(UNIT=7)

C  DETERMINE NUMBER OF DATA POINTS, RANGE OF CONCENTRATIONS

      NUM=I-1
      CRANGE=CMAX-CMIN

C  DETERMINE WHERE TO SPLIT DATA SET

      CCUT=CMIN+(0.1*CRANGE)

      DO 30 I=1,NUM

        IF (C(I).LT.CCUT) GOTO 40

   30 CONTINUE

   40 NCUT=I

C  DETERMINE IF ENOUGH DATA IS AVAILABLE TO SPLIT DATA SET FOR
C  TWO FITS, THEN CALL SUBROUTINE TO LINEARIZE EQUATION AND
C  PERFORM REGRESSION TO DETERMINE INITIAL PARAMETER VALUES

      IF(NCUT.LE.4.AND.(NUM-NCUT).LE.3) THEN

        CALL LINREG(NUM,CMIN,COI,CFI,AKI)

      ELSE

        NC1=NCUT-1

        CALL LINREG(NC1,CMIN,CO2,CF2,AKI)

        CALL LINREG(NUM,CMIN,COI,CFI,AK2)

      ENDIF

C  DETERMINE SUM OF SQUARE DEVIATIONS AND CORRELATION COEFFICIENT
C  FOR INITIAL PARAMETER VALUES

      CALL STATS(NUM,COI,CFI,AKI,ALSPI,CORRI)

C  WRITE INITIAL VALUES AND STATISTICS TO OUTPUT FILE

      WRITE(8,45)COI,CFI,AKI,ALSPI,CORRI
   45 FORMAT(F8.2,2X,F8.2,2X,F8.5,2X,F9.2,2X,F6.4)
```

```
C  INITIALIZE STEP FUNCTION AND START ITERATION LOOP

      DELTA=1

   50 ALSPB=ALSPI

      ICHANGE=0

      DO 100 I1=1,3

        DO 99 I2=1,3

          DO 98 I3=1,3

            IF(I1.EQ.1.AND.I2.EQ.1.AND.I3.EQ.1) GOTO 98

C  DETERMINE NEXT ITERATIVE VALUES OF PARAMETERS

            CODEL=COI+(COI*DELTA*CDEL(I1))

            CFDEL=CFI+(CFI*DELTA*CDEL(I2))
            IF(CFDEL.LT.0.0)CFDEL=0.0
            IF(CFDEL.GT.CMIN)CFDEL=CMIN*0.9999

            AKDEL=AKI+(AKI*DELTA*CDEL(I3))

C  CALCULATE STATISTICS FOR NEW PARAMETER VALUES

            CALL STATS(NUM,CODEL,CFDEL,AKDEL,ALSPDEL,CORRDEL)

C  DETERMINE IF NEW PARAMETERS GIVE A SMALLER SUM OF SQUARE
C  DEVIATION VALUE THAN THE PREVIOUS BEST, AND IF SO, SAVE VALUES

            IF (ALSPDEL.LT.ALSPB) THEN

              ICHANGE=1

              ICDEL(1)=I1
              ICDEL(2)=I2
              ICDEL(3)=I3
              ACDEL(1)=ALSPDEL
              ACDEL(2)=CORRDEL

              ALSPB=ALSPDEL

            ENDIF

   98     CONTINUE

   99   CONTINUE

  100 CONTINUE
```

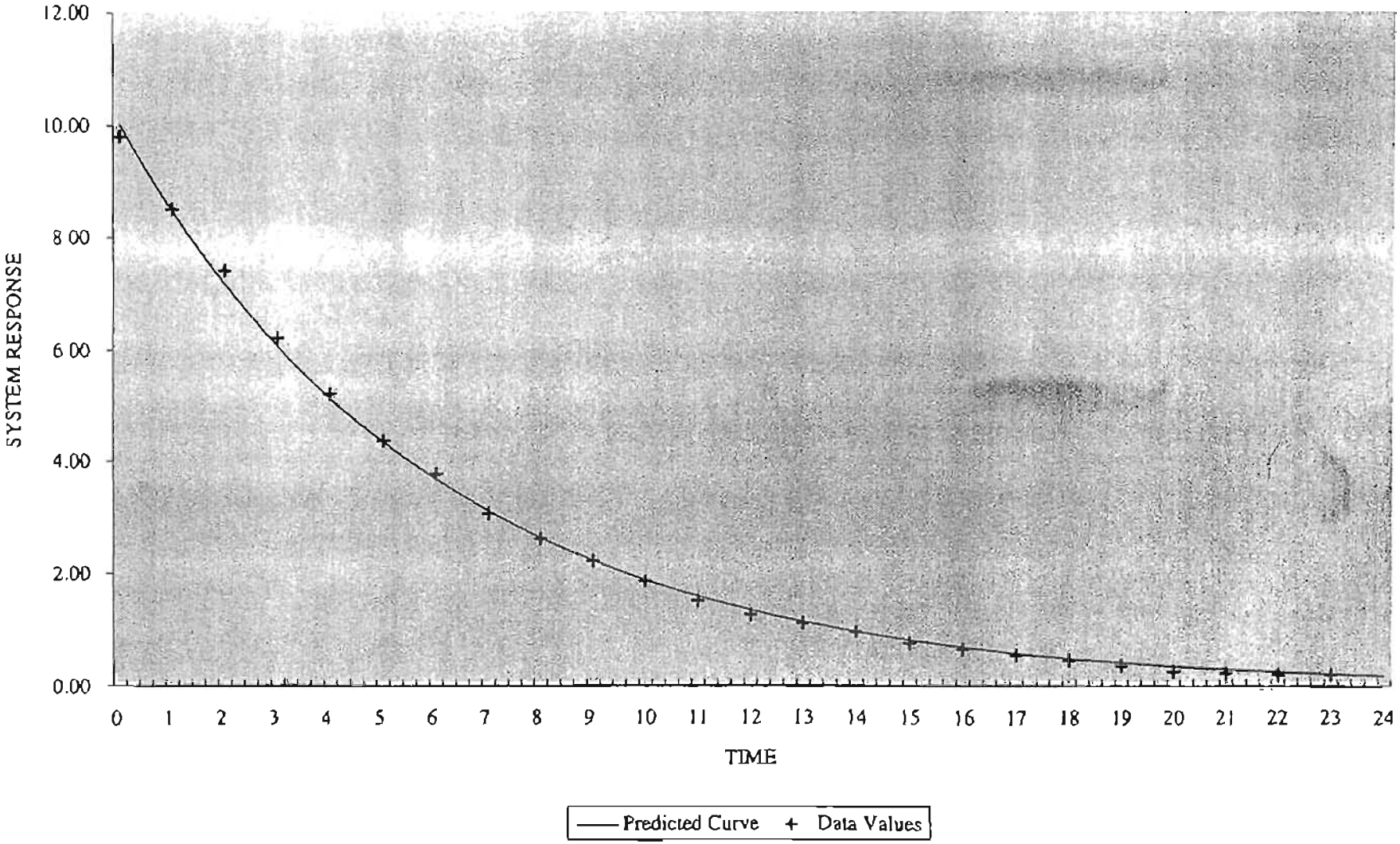
```
C  DETERMINE IF A SMALLER VALUE OF THE SUM OF SQUARE DEVIATIONS
C  WAS FOUND.  IF SO, REINITIALIZE LOOP, SAVE NEW VALUES, AND
C  LOOP AGAIN WITH SAME ITERATION STEP; IF NOT, REDUCE STEP

      IF(ICHANGE.EQ.1) THEN

         ICHANGE=0

         COI=COI+(COI*DELTA*CDEL(ICDEL(1)))
         CFDEL=CFI+(CFI*DELTA*CDEL(ICDEL(2)))

             IF(CFDEL.LT.0.0) THEN
               CFI=0.0
               GOTO 101
             ENDIF

             IF(CFDEL.GT.CMIN) THEN
               CFI=CMIN*0.9999
               GOTO 101
             ENDIF

             CFI=CFDEL

  101 AKI=AKI+(AKI*DELTA*CDEL(ICDEL(3)))

         ALSPI=ACDEL(1)
         CORRI=ACDEL(2)

         WRITE(8,45)COI,CFI,AKI,ALSPI,CORRI

         GOTO 50

      ENDIF

      DELTA=DELTA*0.1

C  DETERMINE IF STEP HAS BEEN REDUCED TO BELOW MINIMUM ALLOWABLE
C  VALUE

      IF(DELTA.EQ.0.001) GOTO 200

      GOTO 50

C  CLOSE OUTPUT FILE

  200 CLOSE(UNIT=8)

      STOP

      END
```

```
C-------------------------------------------------------------------
C-------------------------SUBROUTINES-------------------------------
C-------------------------------------------------------------------
C  THIS SUBROUTINE LINEARIZES THE EXPONENTIAL EQUATION AND
C  PERFORMS REGRESSION ON THE NEW LINEAR FORM
C
      SUBROUTINE LINREG(NUMM,CMIN,COB,CFB,AKB)

      DIMENSION CLOG(30)

      COMMON /TIME/T(30)
      COMMON /CONC/C(30)

      ANUM=NUMM

C  THE LOWER BOUND PARAMETER, Cf, IS STEPPED FROM 99.99% OF
C  MINIMUM VALUE TO 0 IN 10% INCREMENTS.

      CF=CMIN-(CMIN*0.01)

C  BEGIN LOOP OF LOWER BOUND VALUES

      DO 100 J=1,10

C  INTIALIZE REGISTERS

        SUMCL=0.0
        SUMT=0.0
        SUMT2=0.0
        SUMCLT=0.0

        DO 50 I=1,NUMM

          CLOG(I)=ALOG(C(I)-CF)

          SUMCL=SUMCL+CLOG(I)
          SUMT=SUMT+T(I)
          SUMT2=SUMT2+(T(I)*T(I))
          SUMCLT=SUMCLT+(CLOG(I)*T(I))

   50   CONTINUE

        B1=(ANUM*SUMCLT)-(SUMCL*SUMT)
        B2=(ANUM*SUMT2)-(SUMT*SUMT)

        B=B1/B2
        A=(SUMCL-(B*SUMT))/ANUM

C  DETERMINE LEAST SQUARE ESTIMATES OF PARAMETERS K AND Co

        CO=EXP(A)+CF

        AK=B
```

```
C  CALL SUBROUTINE TO DETERINE STATISTICS ON PARAMETERS

      CALL STATS(NUMM,CO,CF,AK,ALSP,CORR)

C  INITIALIZE VALUES DURING FIRST TIME THROUGH LOOP

      IF(J.EQ.1)THEN

        ALSPB=ALSP
        COB=CO
        CFB=CF
        AKB=AK

        GOTO 70

      ENDIF

C  COMPARE NEW VALUE OF THE SUM OF SQUARE DEVIATIONS TO LOWEST
C  VALUE FOUND.  IF LOWER, SAVE VALUE AS NEW BEST VALUE

      IF (ALSP.LT.ALSPB) THEN

        ALSPB=ALSP
        COB=CO
        CFB=CF
        AKB=AK

      ENDIF

C  ITERATE LOWER BOUND, Cf

   70 CF=CF-(CMIN*0.1)

      IF(CF.LT.0.0)CF=0.0

  100 CONTINUE

      RETURN

      END

C
```

```
C  THIS SUBROUTINE DETERMINES THE SUM OF SQUARE DEVIATIONS AND
C  CORRELATION COEFFICIENT FOR MODEL PARAMETERS IN REAL SPACE
C
      SUBROUTINE STATS(NUMM,CO,CF,AK,ALSP,CORR)

      DIMENSION PREDC(30)

      COMMON /TIME/T(30)
      COMMON /CONC/C(30)

      ANUM=NUMM

C  INITIALIZE LOOP REGISTERS

      ALSP=0.0
      SUMP2=0.0
      SUMC2=0.0
      SUMPC=0.0
      SUMC=0.0
      SUMP=0.0

      DO 10 I=1,NUMM

        PREDC(I)=((CO-CF)*EXP(AK*T(I)))+CF

        ALSP=ALSP+((C(I)-PREDC(I))**2)

        SUMP2=SUMP2+(PREDC(I)*PREDC(I))
        SUMC2=SUMC2+(C(I)*C(I))
        SUMPC=SUMPC+(PREDC(I)*C(I))
        SUMP=SUMP+PREDC(I)
        SUMC=SUMC+C(I)

   10   CONTINUE

      CORRA=(ANUM*SUMPC)-(SUMP*SUMC)
      CORRB1=SQRT((ANUM*SUMC2)-(SUMC**2))
      CORRB2=SQRT((ANUM*SUMP2)-(SUMP**2))

      CORR=CORRA/(CORRB1*CORRB2)

      RETURN

      END
```

STEP CHANGE OF INLET CONCENTRATION
THE CORRELATION COEFFICIENT = 0.999



APPENDIX B

CALCULATION OF PATHWAY-SPECIFIC CONCENTRATION LIMITS IN SOIL AND GROUNDWATER

APPENDIX B

CALCULATION OF PATHWAY-SPECIFIC CONCENTRATION LIMITS IN SOIL AND GROUNDWATER

1.00 INTRODUCTION

This appendix presents the procedures and equations used to calculate site-specific risk-based and AWQC-based Pathway-Specific Concentration Limits (PSCLs) in soil and groundwater for the former Digital Equipment Corporation site in San German, Puerto Rico. These PSCLs were used to identify Media Protection Standards (MPS) for soil and groundwater (i.e., the lowest calculated PSCL for a contaminant in a given medium was selected as the MPS) as described in Section 2.22 of the report.

1.10 Methodology

Calculating PSCLs is a multi-step process which incorporates available data and information regarding site use; nature and extent of contamination; site hydrogeology; and contaminant sources to identify (1) media and chemicals of concern; (2) potential receptors, exposure pathways and exposure points; (3) toxicity information; and (4) applicable standards.

The procedures which were applied to calculate these PSCLs are similar to those used to conduct a baseline risk assessment (U.S. EPA, December 1989). However, rather than estimating exposure point concentrations to calculate average daily doses and, subsequently, hazard indices and cancer risk estimates, a target risk level (based on noncarcinogenic or carcinogenic effects, or the lowest applicable standard (in this case, U.S. EPA Ambient Water Quality Criteria, AWQC) is used as the starting point to "backcalculate" a target dose and a concentration at an exposure point which does not exceed an acceptable risk limit (i.e., in this case, a PSCL).

As described in this appendix, we calculated site-specific PSCLs for groundwater based on several exposure pathways (refer to Section 3.00). These were: (1) potential dermal contact exposure to groundwater by hypothetical (future) utility workers, (2) potential inhalation of VOC vapors in indoor air by facility workers who are employed in site buildings, and (3) potential migration of contaminants in site groundwater to the Guanajibo River. PSCLs for groundwater for both overburden and bedrock groundwater were calculated. For soil, we calculated site-specific risk-based PSCLs based on potential dermal contact and incidental ingestion exposure to soil within the loading dock area by hypothetical (future) utility workers.

3.10 Identification of Potential Receptors, Exposure Points, and Exposure Pathways

Facility workers who are employed in site buildings may inhale volatile contaminants in indoor air from two different source media: soil gas and industrial process water. VOCs detected in soil gas beneath Buildings 1 and 2 may migrate from the vadose zone soils to indoor air. Additionally, use of groundwater as a source of industrial process water for the site facility may also contribute to VOC levels in indoor air within site buildings. Since areas surrounding site buildings are paved, dermal contact and incidental ingestion of contaminants in surface soil by facility workers is not a complete exposure pathway.

Utility workers may be exposed to VOCs in surficial and subsurface soil via dermal contact and incidental ingestion during hypothetical (future) subsurface utility work (e.g. installation/repair of utility lines) within the loading dock area. Although metals were detected in soil samples collected from the loading dock area, they were considered to be consistent with background levels (refer to Section 6.31 of the Phase I report and Section 4.30 of the Phase II report). Based on groundwater elevation measurements made in November 1994, December 1994, and January 1995, utility workers may encounter groundwater during hypothetical (future) subsurface utility work on the west/northwest portion of the site and would therefore be exposed to VOCs in groundwater via dermal contact.

As described in the Phase II report, historical water resource data for the Guanajibo River indicate that water quality has been poor due to sewage discharges. Data for a sampling point located upstream of the site (near GZA sample location SW-1) indicate elevated coliform, fecal coliform, and fecal streptococci. Therefore, given the historically poor water quality, local residents (adults and children) are unlikely to use the river for recreational purposes such as swimming, fishing or boating. However, to be conservative, we identified local residents as potential receptors who may be exposed to contaminants in the Guanajibo River through consumption of fish from the river.

Freshwater aquatic life in the Guanajibo River were identified as potential ecological receptors who may be exposed to contaminants which may migrate in groundwater to the river, and therefore, exposure of freshwater aquatic life to contaminants in the Guanajibo River was also identified as a complete exposure pathway.

GZA conducted a survey of public and private drinking water supply wells near the site. Based on the results of this survey, use of groundwater as a source of drinking water was not identified as a complete exposure pathway.

As indicated above, the PSCLs for overburden and bedrock groundwater were based on the following potential exposure pathways: (1) dermal contact with groundwater by hypothetical (future) utility workers, (2) inhalation of VOC vapors in indoor air by facility

workers, and (3) migration of contaminants in site groundwater to the Guanajibo River. PSCLs for soil were based on dermal contact and incidental ingestion of soil within the loading dock area by hypothetical (future) utility workers.

3.20 Calculation of Exposure Factors

Receptor-specific exposure factors are incorporated into equations to calculate risk-based concentrations in soil and groundwater. These exposure factors include receptor-specific information regarding exposure such as body weight, duration and frequency of exposure, soil adherence factor, skin surface area, daily soil ingestion rate, and inhalation rates. Assumptions regarding exposure for the receptors identified above are presented in Tables B.2 through B.5.

4.00 IDENTIFICATION OF CHEMICALS OF CONCERN

Chemicals of concern (i.e., the contaminants for which we calculated PSCLs) were identified based on a review of analytical data gathered during hydrogeologic investigations of the site and information contained in the conceptual site model (refer to GZA's Phase I and Phase II reports). Specifically, contaminants detected in samples collected from identified exposure points (e.g., the loading dock area) or at points of compliance (in the case of site groundwater which contributes to surface water discharge) were selected as chemicals of concern, with some exceptions as described below.

Table B.6 contains a list of the chemicals of concern for which site-specific risk-based PSCLs were calculated. With the exception of metals in soil and groundwater which are assumed to be consistent with background levels, all contaminants detected at applicable sample locations within identified exposure points or points of compliance were included as chemicals of concern for which PSCLs for soil and groundwater were calculated. The following two sections provide an explanation of the sample locations and analytical data used to identify chemicals of concern.

4.21 Groundwater

Based on our assessment of potential exposure scenarios, utility workers may encounter groundwater during hypothetical (future) subsurface utility work at the site. Therefore, to be protective of potential worker exposures to contaminants in groundwater, we reviewed analytical data for groundwater samples collected in 1993 and 1994 from monitoring wells where depth to groundwater (based on 1994 and 1995 groundwater elevation measurements) was measured at 0 to 8 feet below ground surface (i.e., OW-2, OW-103, OW-105, OW-106, OW-303A, OW-305, OW-404U). The following contaminants, detected in groundwater at these locations (i.e., chloroform, 1,1-dichloroethene (1,1-DCE), cis 1,2-dichloroethene (cis 1,2-DCE), 1,2-dichloroethane (1,2-DCA), and trichloroethene

(TCE)), were identified as chemicals of concern. PSCLs for overburden groundwater were calculated for each of these chemicals.

As discussed in Section 3.10, two different source media (soil gas and use of groundwater used as industrial process water) may contribute to VOC vapors in indoor air within the site buildings. To determine the relative contribution of each of these sources to the total risk for a facility worker (assuming that the source of soil gas is associated with contaminants in groundwater), we calculated HIs and cancer risk estimates based on estimated indoor air EPCs (from VOC concentrations detected in soil gas and from VOC concentrations in groundwater used a process water). We used the assumptions for facility worker exposures to indoor air presented in Table B.5 to conduct this evaluation. Refer to Appendix B-1 for the methodology used to calculate noncarcinogenic HIs and cancer risk estimates for the facility worker.

Results of this evaluation indicate that noncarcinogenic effects associated with inhalation of VOCs in indoor air associated with soil gas beneath site buildings are negligible compared to those associated with inhalation of VOCs from use of groundwater as industrial process water (refer to Tables B-1.2 and B-1.3 for results). Therefore, to be protective of potential inhalation exposures for workers in site buildings, assuming continued use of groundwater as a process water, two VOCs (i.e., cis 1,2-DCE and TCE) detected in a sample of the process water in December 1994, were identified as chemicals of concern. PSCLs for bedrock groundwater were calculated for these two chemicals.

Based on previous hydrogeologic studies of the site, groundwater flows in a north/northwesterly direction toward the Guanajibo River. To be protective of freshwater aquatic life in the Guanajibo River and potential risks to human health associated with fish consumption, we identified points of compliance (i.e., locations which represent the entire portion of the site which contributes to surface water discharge). Points of compliance include the following monitoring wells: W-1, W-6, W-7, BR-308, OW-102, OW-304, OW-401, OW-404U, OW-404L, and OW-405. Contaminants detected in groundwater samples collected from these locations during the Phase I and Phase II studies in 1993 and 1994 were identified as chemicals of concern (refer to table B.6 for a list of these chemicals). PSCLs for overburden and bedrock groundwater were calculated for these chemicals.

4.22 Soil

Based on GZA's Phase II study, the loading dock area between Buildings 1 and 5 is a confirmed source area. Analytical data for soil samples collected from borings completed within the loading dock area (i.e., B-413, B-414, and OW-408), elevated levels of VOCs and metals are present in soil. As indicated above, levels of metals in soil are assumed to be consistent with background levels. Utility workers may be exposed to

contaminants in surface and subsurface soil within the loading dock area during hypothetical (future) subsurface utility work within this area. Therefore, VOCs (i.e., cis 1,2-DCE, trans 1,2-DCE and TCE) detected in soil samples collected at these three locations, at depths of 0 to 8 feet below ground surface, were identified as chemicals of concern for which PSCLs in soil were calculated.

5.00 TOXICITY INFORMATION

Toxicity information is used to quantitatively characterize the relationship between the dose of a contaminant and the incidence of adverse health effects in an exposed population. We identified readily available toxicity values for all of the contaminants for the exposure pathways under evaluation. Using information obtained from published literature describing epidemiologic or toxicologic studies involving a particular contaminant, the U.S. EPA has derived contaminant-specific reference doses (RfDs) and reference concentrations (RfCs) for threshold (noncancer) effects and Cancer Slope Factors (CSFs) and inhalation unit risks for nonthreshold (cancer) effects. The values were developed to assess ingestion and inhalation exposures. No values have been established for dermal contact exposures; however, in accordance with standard risk assessment practice (U.S. EPA, December 1989), values derived for ingestion were used to evaluate dermal contact exposures.

The hierarchy for gathering toxicity values for calculation of risk-based concentrations is the same as that used in the baseline risk assessment. We used U.S. EPA's Integrated Risk Information System (IRIS) (U.S. EPA, July 1995) as the primary source for toxicity information. If no verified toxicity value was available through IRIS, we referred to the Health Effects Assessment Summary Tables (HEAST) (U.S. EPA, March 1994). IRIS does not provide subchronic RfDs; therefore, these values were obtained from HEAST. If a subchronic RfD was not available for a given chemical during preparation of the risk assessment, the chronic RfD was used as a default value. In the absence of EPA approved toxicity information for some of the contaminants, we used Massachusetts Department of Environmental (MADEP) values (MADEP, October 1992). MADEP is used as a convenient backup source of toxicity information since the agency has derived toxicity values using U.S. EPA methodology.

5.10 Threshold Toxicity Values

For noncarcinogenic health effects, a threshold is assumed to exist below which no adverse health effects would be expected to occur. U.S. EPA generates dose-response values for noncarcinogenic effects, called RfDs, by applying uncertainty factors to a No-Observed-Adverse-Effect Level (NOAEL) or to a Lowest-Observed-Effect Level (LOAEL), obtained from studies of dose-response relationships. The purpose of these uncertainty factors is to establish exposure levels that are health protective even for sensitive receptors such as the elderly. Uncertainty Factors are used as appropriate, to account for interspecies

variability between humans and other mammals used in the dose-response studies; use of a NOAEL derived from a subchronic rather than a chronic study; uncertainty when extrapolating from LOAELs to NOAELs; and variation in the sensitivity of the human population. A Modifying Factor is an additional factor used in the estimation of allowable levels that allows for "professional judgement" regarding confidence in the studies.

The chronic RfD (oral) and RfC (inhalation), which may incorporate modifying factors and uncertainty factors, are conservative estimates of an average daily exposure level for humans, below which no adverse noncarcinogenic health effects are expected to occur over long periods of exposure. The units of the RfD are mg/kg-day (mg chemical/kg body weight per day). The units of the RfC are mg/m^3 (mg chemical/m^3 volume of air). The subchronic RfD and RfC are calculated in a manner analogous to the chronic benchmarks, however, they are designed to be protective of shorter duration exposures (generally defined as representing exposures occurring from over three months to less than 10 percent of a lifetime).

5.11 Reference Doses

The RfD is a conservative estimate of an average daily exposure level below which no adverse noncarcinogenic (threshold) health effects are expected. Chronic RfDs represent a human exposure level of a chemical, expressed in mg/kg-day (mg of contaminant per kg of receptor body weight per day), that is not likely to cause adverse effects when exposure is long-term. RfDs were originally developed for lifetime exposure; however, subchronic RfDs have been developed to assess shorter exposures occurring over three months to less than 10 percent of a lifetime (seven years).

5.12 Reference Concentrations

RfCs are inhalation exposure concentrations to which daily exposure of a human population, including sensitive populations, is likely to be without appreciable effects. U.S. EPA considers it to be inappropriate to convert agency-approved RfCs to RfDs. Since RfCs generally measure toxic effects at the point of entry (i.e., the lungs or nasal tissues), they cannot be normalized according to bodyweight, which would be necessary to convert from an RfC to an RfD.

Noncarcinogenic toxicity information, used to calculate PSCLs, is presented in Tables B.7 and B.8.

5.20 Carcinogenic Effects

For carcinogenic effects, the dose-response curve indicates the relationship between the dose and the probability of developing cancer. Carcinogens are assumed to act without

a threshold. For carcinogenic substances, it is assumed that there is some level of cancer risk associated with every nonzero dose. Toxicity information for chemicals suspected of being human carcinogens includes a weight-of-evidence classification and an (oral) Cancer Slope Factor (CSF) or (inhalation) unit risk. The weight-of-evidence classification indicates the likelihood that a compound is a human carcinogen based on the quality of evidence from human and animal studies and other supportive information such as mutagenic effects or structure-activity data. The CSF is an estimate of the cancer-causing potency of a substance in humans. The unit risk is the risk per unit concentration in air.

5.21 Cancer Slope Factors

CSFs are derived by the U.S. EPA's Carcinogen Assessment Group (CAG) using the linearized multistage model (for animal data) to extrapolate from high experimental doses to low environmental doses. The dose-response curve indicates the relationship between the dose of a particular chemical and the probability of obtaining cancer over a lifetime. The U.S. EPA utilizes the 95th percent upper confidence limit of the slope of the dose-response curve from the multistage model (the CSF), expressed in $(mg/kg\text{-}day)^{-1}$. Use of a CSF assumes that the calculated dose received is expressed as a lifetime average, in units of mg/kg-day.

5.22 Unit Risks

The unit risk is the upper 95 percent confidence limit of the mean cancer risk estimated to result from lifetime exposure to an agent if it is in the air at a concentration of 1 ug/m^3 or in drinking water at a concentration of 1 ug/l. These values are used in lieu of a CSF when an estimate of a lifetime average concentration of a contaminant is being utilized.

Toxicity information for carcinogenic substances, used to calculate PSCLs, is presented in Table B.9.

6.00 CHEMICAL-SPECIFIC PARAMETERS

Chemical-specific parameters (i.e., absorption adjustment factors and permeability coefficients) were also incorporated into the calculation of PSCLs, as described below.

6.10 Absorption Adjustment Factors

Contaminant- and media-specific absorption adjustment factors (AAFs) were applied to the calculated chemical-specific target doses to make them compatible with the chemical-specific toxicity values. AAFs are necessary to account for differences in the absorption of a contaminant in a given environmental medium relative to that in the dose-response study.

Absorption differences can result from matrix attenuation effects as well as differences in the route of administration (oral versus dermal exposures).

Additionally, AAFs can be used to convert an exposure dose to an absorbed dose, in cases where a dose-response value is based on absorbed dose. Finally, for dermal exposure to water, an absorbed dose is calculated. Thus, the AAF can be used to convert the dose-response value to an absorbed dose so that it is compatible with the dose estimate.

Massachusetts Department of Environmental Protection (MADEP) derived AAFs were used when available. MADEP is the only regulatory agency GZA is aware of that has calculated AAFs using the methodology outlined by RAGS (U.S. EPA, December 1989). When not available for a given chemical of concern, GZA derived the appropriate AAFs using EPA methodology. MADEP (MADEP, October 1992) has not, however, derived any AAFs for dermal exposure to water. Therefore, GZA derived AAFs to evaluate exposure via dermal contact. Table B.10 presents the AAFs used to calculate PSCLs for soil and groundwater.

6.20 Permeability Coefficients

The permeability coefficient (Kp) is a key parameter used in estimating dermal absorption of contaminants in water. Kp (cm/hour) represents the dermal permeability of a contaminant from an aqueous vehicle through the skin. Experimentally measured or estimated Kp values were used for contaminants in aqueous media using data and equations provided by the EPA (U.S. EPA, January 1992). These Kp values were incorporated into the equation used to calculate the dose for dermal contact with groundwater. Since the permeability coefficient is used to calculate the amount of contaminant penetrating the skin, the resulting dose is an absorbed dose. Table B.11 presents the permeability coefficients used to calculate risk-based concentrations in groundwater.

7.00 IDENTIFICATION OF APPLICABLE STANDARDS

We identified applicable standards based on the potential human and ecological receptors, exposure points, and exposure pathways identified in Section 3.00 above. Based on hydrogeologic studies of the site, groundwater flows in a north/northwesterly direction toward the Guanajibo River. Aquatic organisms in the Guanajibo River may be exposed to contaminants which migrate in groundwater toward and into the river. Therefore, AWQC for aquatic organisms (freshwater acute and chronic water quality benchmarks) were identified as applicable standards.

Based on historical water resource data for the for the Guanajibo River which indicate poor water quality due to sewage discharge, and the industrial nature of the areas near the river, it is unlikely that local residents use the Guanajibo River for recreational purposes such as

swimming, fishing, or boating. However, to be conservative, we assumed that local residents may be exposed to contaminants via fish consumption. Accordingly, AWQC for the protection of human health with respect to fish ingestion were also identified as applicable standards.

Table B.12 provides a summary of the water quality benchmarks for human health (fish consumption) and freshwater aquatic life (acute and chronic). The lowest of the available benchmarks for each chemical of concern was used to represent the Guanajibo River.

Since neither groundwater nor surface water are current or potential future sources of drinking water, federal Maximum Contaminant Levels (MCLs), non-zero Maximum Contaminant Level Goals (MCLGs), and AWQC for the protection of human health from water ingestion exposures, were not identified as applicable standards. In addition, the Commonwealth of Puerto Rico has not promulgated drinking water standards.

8.00 CALCULATION OF PATHWAY-SPECIFIC CONCENTRATION LIMITS

GZA developed PSCLs for use in establishing MPSs for soil and groundwater. PSCLs were developed based on site-specific considerations and pathways by which identified receptors may be exposed to contaminants.

PSCLs are concentrations for individual contaminants that correspond to a target risk for noncarinogenic and carcinogenic effects. For carcinogenic effects, the target risk level is a cancer risk of 10^{-6} and for noncarcinogenic effects, the target risk level is a Target Hazard Index (THI) of 1.0. A target organ-specific approach was used to calculate PSCLs, whereby a THI of 1.0 was apportioned equally across all chemicals in a given medium which affect a specific target organ. These target risks are combined with exposure and toxicity information to calculate PSCLs. The lowest PSCL for a contaminant in a given medium (i.e., soil or groundwater) was selected as the MPS.

The general equations used to calculate PSCLs in soil and groundwater based on noncarcinogenic and carcinogenic effects for the identified human receptors and exposure pathways are presented in Sections 8.10 and 8.20 below. AWQC were used to calculate PSCLs for overburden and bedrock groundwater (refer to Section 8.30 below). Calculated PSCLs for soil and groundwater are presented in Tables B.13 through B.16.

8.10 Calculation of Pathway-Specific Concentration Limits for Soil Based on Noncarcinogenic and Carcinogenic Effects

PSCLs for each contaminant were calculated by considering all of the relevant exposure pathways. In the case of soil, risks from two exposure pathways (i.e., dermal

contact and incidental ingestion) are combined, and the PSCL is derived to be protective of exposures from both pathways.

Noncarcinogenic Effects:

$$THI_n = \sum_{i=n}^{i=1} \frac{1}{n} \left\{ \left[\frac{C_{soil_i}\left(\frac{mg}{kg}\right) \cdot EF_{dc}\left(\frac{kg}{kg\text{-}day}\right) \cdot AAF_{dc\text{-}soil}}{RfD_i\ (mg/kg\text{-}day)} \right] + \left[\frac{C_{soil_i}\left(\frac{mg}{kg}\right) \cdot EF_{ii}\left(\frac{kg}{kg\text{-}day}\right) \cdot AAF_{ii\text{-}soil}}{RfD_i\ (mg/kg\text{-}day)} \right] \right\}$$

where,

n	=	number of compounds affecting a target organ
C_{soil_i}	=	Concentration in soil for Compound i (mg/kg)
THI_n	=	Target Hazard Index for n Compounds exhibiting an effect on a given target organ = 1.0
RfD_i	=	Reference Dose for Compound i (mg/kg-day)
AAF	=	Absorption Adjustment Factor
EF_{dc}	=	Receptor-Specific Exposure Factor for dermal contact with soil (kg/kg-day)
EF_{ii}	=	Receptor-Specific Exposure Factor for incidental ingestion of soil (kg/kg-day)

PSCLs in soil based on noncarcinogenic effects are calculated by solving for C_{soil_j} as follows:

$$THI_n = \frac{1}{n} \times \frac{C_{soil_i}}{RfD_i} \left\{ \left[EF_{dc} \cdot AAF_{dc-soil} \right] + \left[EF_{ii} \cdot AAF_{ii-soil} \right] \right\}$$

$$C_{soil_i} = \frac{THI_n \cdot RfD_i \cdot n}{\left\{ \left[EF_{dc} \cdot AAF_{dc-soil} \right] + \left[EF_{ii} \cdot AAF_{ii-soil} \right] \right\}}$$

Carcinogenic Effects:

$$TR_i = [C_{soil_i}\ (mg/kg) * EF_{dc}\ (kg/kg\text{-}day) * AAF_{dc\text{-}soil} * CSF_{oral_i}\ (mg/kg\text{-}day)^{-1}] + [C_{soil_i}(mg/kg) * EF_{ii}\ (kg/kg\text{-}day) * AAF_{ii\text{-}soil} * CSF_{oral_i}\ (mg/kg\text{-}day)^{-1}]$$

where,

TR_i = Target Excess Lifetime Cancer Risk for Compound i = 1.0×10^{-6}

CSF_{oral_i} = Oral Cancer Slope Factor for Compound i $(mg/kg\text{-}day)^{-1}$

PSCLs in soil based on carcinogenic effects are calculated by solving for C_{soil_i} as follows:

$$C_{soil_i}\ (mg/kg: risk\text{-}based) = TR_i / \{CSF_{oral_i}\ (mg/kg\text{-}day)^{-1} * [(EF_{dc}\ (kg/kg\text{-}day) * AAF_{dc\text{-}soil}) + (EF_{ii}\ (kg/kg\text{-}day) * AAF_{ii\text{-}soil})]\}$$

8.20 Calculation of Pathway-Specific Concentration Limits for Groundwater Based on Noncarcinogenic and Carcinogenic Effects

PSCLs for overburden and bedrock groundwater were calculated by considering all of the relevant exposure pathways. PSCLs for overburden groundwater were calculated to be protective of potential risks for: (1) utility workers who may contact shallow groundwater, and (2) potential risks to freshwater aquatic life in the Guanajibo River and potential risks to human health with respect to fish consumption. PSCLs for bedrock groundwater were calculated to be protective of potential risks for: (1) facility workers who may inhale VOC vapors in indoor air associated with use of bedrock groundwater as process water, and (2) freshwater aquatic life in the Guanajibo River and human health with respect to fish consumption.

Noncarcinogenic Effects:

$$THI_n = \sum_{i=n}^{i=1} \frac{1}{n} \left[\frac{C_{water_i}\left(\frac{mg}{l}\right) \cdot EF_{dc}\left(\frac{l\text{-}hr}{cm\text{-}kg\text{-}day}\right) \cdot AAF_{dc\text{-}water} \cdot Kp\ (cm/hr)}{RfD_i (mg/kg\text{-}day)} \right]$$

where,

C_{water_i} = Concentration in groundwater for Compound i (mg/l)

EF_{dc} = Receptor-Specific Exposure Factor for dermal contact with groundwater (*l*-hr/(cm-kg-day)

Kp = Permeability Coefficient (cm/hour)

PSCLs in groundwater based on noncarcinogenic effects are calculated by solving for C_{water_i} as follows:

$$THI_n = \frac{1}{n} \cdot \frac{C_{water_i}}{RfD_i} \left[EF_{dc} \cdot AAF_{dc} \cdot Kp \right]$$

$$C_{water_i} = \frac{THI_n \cdot n \cdot RfD_i}{[EF_{dc} \cdot AAF_{dc} \cdot Kp]}$$

Carcinogenic Effects:

$$TR_i = C_{water_i}\ (mg/l) * EF_{dc}\ (l\text{-hour/cm-kg-day}) * AAF_{dc\text{-water}} * Kp\ (cm/hour) * CSF_{oral_i}\ (mg/kg\text{-day})^{-1}$$

PSCLs in groundwater based on carcinogenic effects are calculated by solving for C_{water_i} as follows:

$$C_{water_i}\ (mg/l\text{: risk-based}) = TR/[EF_{dc}\ (l\text{-hour/cm-kg-day}) * AAF_{dc\text{-water}} * Kp\ (cm/hour) * CSF_{oral}\ (mg/kg\text{-day})^{-1}]$$

8.30 Calculation of Pathway-Specific Concentration Limits for Groundwater Based on AWQC

To be protective of freshwater aquatic life in the Guanajibo River and potential exposures to human health with respect to fish consumption, AWQC were used to represent applicable standards for the Guanajibo River. To "backcalculate" concentrations in site groundwater at points of compliance which would not cause a concentration in the Guanajibo River which exceeds an acceptable risk limit (in this case,), we calculated dilution factors which account for dilution of contaminants as they migrate toward and into the Guanajibo (refer to Appendix B-2). These dilution factors were incorporated into our calculation of PSCLs in groundwater. Please refer to Table B.16 for the equations used to derive the PSCLs for overburden and bedrock groundwater based on AWQC.

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TABLES

TABLE B.1

POTENTIAL RECEPTORS, EXPOSURE POINTS, AND EXPOSURE PATHWAYS
Digital Equipment Corporation
San German, Puerto Rico

Receptor	Activity	Exposure Point	Medium	Time	Exposure Pathway(s)
Facility Worker	Employment	Site Building	Indoor Air (VOC Vapors)	Current and Future	Inhalation
Utility Worker	Installation/Repair of Utility lines	Loading Dock	Surficial and Subsurface Soil	Future	Dermal Contact/ Incidental Ingestion
	Installation/Repair of Utility lines	Site	Groundwater	Future	Dermal Contact
Local Residents	Fishing	Guanahibo River	Fish	Future	Fish Consumption
Environmental Receptors	Aquatic Organism Activities	Guanahibo River	Surface Water	Future	Bioaccumulation/ Uptake

TABLE B.2

CALCULATION OF RECEPTOR - SPECIFIC EXPOSURE FACTORS
DERMAL CONTACT WITH SOIL
(Utility Worker)

VARIABLES	EXPOSURE ASSUMPTIONS AND REFERENCES	NOTES
Person	Utility Worker	1
Age	18-65 years	1
Average body weight (BW)	70 kilograms	2
Frequency of Exposure (EF)	5 events/year	3
Duration of Exposure Event (ED)	1 day/event	4
Duration of Exposure Period (EP)	1 year	5
Averaging Period (AP)		6
for noncancer risk	1 year	
for cancer risk	70 years	
Skin surface area to contact with soil on days exposed (SA)	10,120 cm^2	7
Skin surface area	23,000 cm^2	
Fraction of skin exposed	arms, hands, and head	
Soil Adherence Factor (AF)	1 mg/cm^2	8

CALCULATION OF RECEPTOR - SPECIFIC EXPOSURE FACTORS FOR DERMAL CONTACT WITH SOIL

SUBCHRONIC NONCARCINOGENIC EFFECTS:

Receptor - Specific Exposure Factor = SA (cm^2) x AF (mg/cm^2 - day) x EF (events/year) x (1 year/365 days)
x ED (days/event) x EP (years) x 1 kg/1,000,000 mg x 1/BW(kg) x 1/AP (years)

Receptor - Specific Exposure Factor (kg/kg-day) = 2.0E-06

CARCINOGENIC EFFECTS:

Receptor - Specific Exposure Factor = SA (cm^2) x AF (mg/cm^2 - day) x EF (events/year) x (1 year/365 days)
x ED (days/event) x EP (years) x 1 kg/1,000,000 mg x 1/BW(kg) x 1/AP (years)

Receptor - Specific Exposure Factor (kg/kg-day) = 2.8E-08

NOTES:

1. Utility workers, 18 to 65 years of age, were used to represent hypothetical (future) receptors who may be exposed to contaminants in soil during subsurface utility work within the loading dock area.

2. Average body weight of the receptor population obtained from U.S. EPA, Office of Solid Waste and Emergency Response. Human Health Evaluation Manual, Supplemental Guidance: "Standard Default Exposure Factors," OSWER Directive 9285.6-03, March 1991.

3. Frequency of exposure describes how often the exposure event occurs over a given period of time. It was assumed that workers would be exposed to contaminants in soil during 5 day period of hypothetical (future) subsurface utility work within the loading dock area.

4. The duration of each exposure event describes how long each individual exposure event might last. For dermal contact exposure to soil, exposure duration is 1 event/day. During this event, the worker is assumed to receive the daily intake of contaminants.

5. The duration of the exposure period describes the length of time over which the utility worker comes into contact with soil.

6. For noncancer risks, the averaging period is set equal to the exposure period (in this case, 1 year). The averaging period is equal to a lifetime (i.e., 70 years) when estimating cancer risks.

7. Skin surface area based on U.S. EPA, Dermal Exposure Assessment: Principles and Applications, Interim Report, Office of Research and Development, Washington, D.C., EPA 600/8-91/001B, January 1992. Fraction of skin exposed was assumed to be arms, hands, and head based on hypothetical work activities.

8. Soil adherence factor obtained from U.S EPA Dermal Exposure Assessment Principles and Applications, Interim Report, Office of Research and Development, Washington, D.C., EPA 600/8-91/001B, January 1992.

TABLE B.3

CALCULATION OF RECEPTOR - SPECIFIC EXPOSURE FACTORS
INCIDENTAL INGESTION OF SOIL
(Utility Worker)

VARIABLES	EXPOSURE ASSUMPTIONS AND REFERENCES	NOTES
Person	Utility Worker	1
Age	18-65 years	1
Average body weight (BW)	70 kilograms	2
Frequency of Exposure (EF)	5 events/year	3
Duration of Exposure Event (ED)	1 day/event	4
Duration of Exposure Period (EP)	1 year	5
Averaging Period (AP)		6
for noncancer risk	1 year	
for cancer risk	70 years	
Daily soil ingestion rate on days exposed (IR)	480 mg/day	7

CALCULATION OF RECEPTOR - SPECIFIC EXPOSURE FACTORS FOR INCIDENTAL INGESTION FOR SOIL

SUBCHRONIC NONCARCINOGENIC EFFECTS:

Receptor - Specific Exposure Factor = IR (mg/day) x EF (events/year) x (1 year/365 days) x ED (days/event) x EP (years) x 1 kg/1,000,000 mg x 1/BW (kg) x 1/AP (years)

Receptor - Specific Exposure Factor (kg/kg-day) = 9.4E-08

CARCINOGENIC EFFECTS:

Receptor - Specific Exposure Factor = IR (mg/day) x EF (events/year) x (1 year/365 days) x ED (days/event) x EP (years) x 1 kg/1,000,000 mg x 1/BW (kg) x 1/AP (years)

Receptor - Specific Exposure Factor (kg/kg-day) = 1.3E-09

NOTES:

1. Utility workers, 18 to 65 years of age, were used to represent hypothetical (future) receptors who may be exposed to contaminants in soil during subsurface utility work within the loading dock area.

2. Average body weight of the receptor population obtained from U.S. EPA, Office of Solid Waste and Emergency Response, Human Health Evaluation Manual, Supplemental Guidance: "Standard Default Exposure Factors," OSWER Directive 9285.6-03, March 1991.

3. Frequency of exposure describes how often the exposure event occurs over a given period of time. It was assumed that workers would be exposed to contaminants in soil during 5 day period of hypothetical (future) subsurface utility work within the loading dock area.

4. The duration of each exposure event describes how long each individual exposure event might last. For incidental ingestion exposure to soil, exposure duration is 1 event/day. During this event, the worker is assumed to receive the daily intake of contaminants.

5. The duration of the exposure period describes the length of time over which the utility worker comes into contact with soil.

6. For noncancer risks, the averaging period is set equal to the exposure period (in this case, 1 year). The averaging period is equal to a lifetime (i.e., 70 years) when estimating cancer risks.

7. Daily soil ingestion rate obtained from U.S. EPA, Office of Solid Waste and Emergency Response, Human Health Evaluation Manual, Supplemental Guidance: "Standard Default Exposure Factors," OSWER Directive 9285.6-03, March 1991, Attachment B.

TABLE B.4

CALCULATION OF RECEPTOR - SPECIFIC EXPOSURE FACTORS
DERMAL CONTACT WITH GROUNDWATER
(Utility Worker)

VARIABLES	EXPOSURE ASSUMPTIONS AND REFERENCES	NOTES
Person	Utility Worker	1
Age	18 - 65 years	1
Average body weight (BW)	70 kilograms	2
Frequency of Exposure (EF)	5 events/year	3
Duration of Exposure Event (ED)	2 hours/event	4
Duration of Exposure Period (EP)	1 year	5
Averaging Period (AP)		6
for noncancer risk	1 year	
for cancer risk	70 years	
Skin surface area in contact with soil on days exposed (SA)	7,360 cm^2	7
Skin surface area	23,000 cm^2	
Fraction of skin exposed	arms and hands	

CALCULATION OF RECEPTOR - SPECIFIC EXPOSURE FACTORS FOR DERMAL CONTACT WITH GROUNDWATER

SUBCHRONIC NONCARCINOGENIC EFFECTS:

Receptor - Specific Exposure Factor = 1/BW (1/kg) x ED (hours/event) x EF (events/year) x EP (years) x 1 year/365 days x SA (cm^2) x 1/AP (years) x 1 liter/1000 cm^3

Receptor-Specific Exposure Factor (l-hour/cm-kg-day) = 2.9E-03

CARCINOGENIC EFFECTS:

Receptor - Specific Exposure Factor = 1/BW (1/kg) x ED (hours/event) x EF (events/year) x 1 year/365 days x EP (years) x SA (cm^2) x 1 liter/1000 cm^3 x 1/AP (years)

Receptor-Specific Exposure Factor (l-hour/cm-kg-day) = 4.1E-05

NOTES:

1. Utility workers, 18 to 65 years of age, were used to represent hypothetical (future) receptors who may be incidentally exposed to contaminants in groundwater during subsurface utility work at the site.

2. Average body weight of the receptor population obtained from U.S. EPA, Office of Solid Waste and Emergency Response. Human Health Evaluation Manual, Supplemental Guidance; "Standard Default Exposure Factors." OSWER Directive 9285.6-03, March 1991.

3. Frequency of exposure describes how often the exposure event occurs over a given period of time. It was assumed that workers would be exposed to contaminants in groundwater during 5 day period of hypothetical (future) subsurface utility work at the site.

4. The duration of each exposure event describes how long each individual exposure event might last. For dermal exposure to groundwater, duration was set at 2 hours per event.

5. The duration of the exposure period describes the length of time over which the utility worker comes in contact with groundwater. The exposure period was set at 1 year.

6. The averaging factor for noncancer is set equal to the exposure period (in this case, 1 year). The averaging period is equal to a lifetime (i.e., 70 years) when estimating cancer risks.

7. Skin surface area based on U.S. EPA. Dermal Exposure Assessment: Principles and Applications, Interim Report, Office of Research and Development, Washington, D.C., EPA 600/8-91/011B, January 1992. Fraction of skin exposed was assumed to be arms and hands based on hypothetical work activities.

TABLE B.5

CALCULATION OF RECEPTOR - SPECIFIC EXPOSURE FACTORS
INHALATION OF INDOOR AIR
(Facility Worker)

VARIABLES	EXPOSURE ASSUMPTIONS AND REFERENCES	NOTES
Person	Facility Worker	1
Frequency of Exposure (EF)	250 events/year	2
Duration of Exposure Event (ED)	8 hours/event	3
Duration of Exposure Period (EP)	25 years	4
Averaging Period (AP)		5
for noncancer risk	25 years	
for cancer risk	70 years	

CALCULATION OF RECEPTOR - SPECIFIC EXPOSURE FACTORS FOR INHALATION OF INDOOR AIR

CHRONIC NONCARCINOGENIC EFFECTS:

Receptor-Specific Exposure Factor = EF (events/year) x (1 year/365 days) x ED (hours/event) x (1 day/24 hours) x EP (years) x 1/AP (years)

Receptor-Specific Exposure Factor (unitless) = **2.3E-01**

CARCINOGENIC EFFECTS:

Receptor-Specific Exposure Factor = EF (events/year) x (1 year/365 days) x ED (hours/event) x (1 day/24 hours) x EP (years) x 1/AP (years)

Receptor-Specific Exposure Factor (unitless) = **8.2E-02**

NOTES:

1. Facility workers were used to represent the receptor population at the site who may be exposed to contaminants in indoor air during work in site buildings.
2. Frequency of exposure was assumed to be 250 events per year per U.S. EPA, Office of Solid Waste and Emergency Response, Human Health Evaluation Manual, Supplemental Guidance: "Standard Default Exposure Factors", OSWER Directive 9285.6-03, March 1991.
3. The duration of each exposure event was assumed to be a standard workday (i.e., 8 hours).
4. The duration of the exposure period for workers employed at the site was assumed to be 25 years per U.S. EPA, Office of Solid Waste and Emergency Response, Human Health Evaluation Manual, Supplemental Guidance: "Standard Default Exposure Factors", OSWER Directive 9285.6-03, March 1991.
5. For noncancer risks, the averaging period is set equal to the duration of the exposure period (in this case, 25 years). The averaging period is equal to a lifetime (i.e., 70 years) when estimating cancer risks.

TABLE 8.6

CHEMICALS OF CONCERN
Digital Equipment Corporation
San Germán, Puerto Rico

Receptor	Exposure Pathway (s)	Medium	Exposure Point	Locations Sampled (1)	Contaminants Detected	Notes
Facility Worker	Inhalation	Indoor Air	Site Buildings	Influent	cis 1,2-Dichloroethene Trichloroethene	(2)
Utility Worker	Dermal Contact/ Incidental Ingestion	Soil	Loading Dock	B-413, B-414, OW-408	cis 1,2-Dichloroethene trans 1,2-Dichloroethene Trichloroethene	(3)
	Dermal Contact	Groundwater	Site	OW-2, OW-103, OW-105, OW-106, OW-300A, OW-305, and OW-404U	Chloroform cis 1,2-Dichloroethene 1,2-Dichloroethane Trichloroethene 1,1-Dichloroethane 1,1-Dichloroethene	(4)
Local Residents	Fish Consumption	Fish	Guanajibo River	W-1, W-6, W-7, BR-308, OW-102, OW-304, OW-401, OW-404U, OW-404L, and OW-405	1,1-Dichloroethane 1,1-Dichloroethene 1,2-Dichloroethane Chloroform cis 1,2-Dichloroethene trans 1,2-Dichloroethene Methylene Chloride Tetrachloroethene Trichloroethene Barium Iron Manganese Nickel	(5)
Freshwater Aquatic Life	Bioaccumulation/Uptake	Surface Water	Guanajibo River	W-1, W-6, W-7, BR-308, OW-102, OW-304, OW-401, OW-404U, OW-404L, and OW-405	1,1-Dichloroethane 1,1-Dichloroethene 1,2-Dichloroethane Chloroform cis 1,2-Dichloroethene trans 1,2-Dichloroethene Methylene Chloride Tetrachloroethene Trichloroethene Barium Iron Manganese Nickel	(5)

Notes:

1. All contaminants detected at the locations specified were identified as chemicals of concern with the exception of metals in soil which are assumed to be consistent with background levels.

2. Analytical data for a groundwater sample "Influent" collected from bedrock wells W-1, W-3, W-6, and W-7 was used to identify chemicals of concern in groundwater. These pumping wells provide groundwater which is used as process water at the facility.

3. Analytical results for soil samples, collected at depths of 0 to 8 feet below ground surface, from borings completed within the loading dock area were used to identify chemicals of concern in soil.

4. Analytical results for groundwater samples collected from monitoring wells at the site in 1993 and 1994, where the depth to groundwater is 0 to 8 feet below ground surface (based on 1994 and 1995 water level readings), were used to identify chemicals of concern in groundwater.

5. Analytical results for groundwater samples collected from monitoring wells at the point of compliance were used to identify chemicals of concern for surface water and fish.

TABLE D.7

SUMMARY OF DOSE-RESPONSE INFORMATION - NONCARCINOGENIC EFFECTS - ORAL
Digital Equipment Corporation
San German, Puerto Rico

Contaminant	Oral Subchronic Reference Dose (mg/kg-day)		Oral Chronic Reference Dose (mg/kg-day)		Chronic Oral RfD UF X MF	Target Organ/System	Critical Effect	Study Animal	Study Method
Volatile Organic Compounds									
Chloroform	1.0E-02	a	1.0E-02	a	1000 x 1	liver	cyst formation	dog	oral-diet
1,1-Dichloroethane	1.0E+00	b	1.0E-01	b	1,000	NA	none observed	rat	Inhalation
1,2-Dichloroethane									
cis,-1,2-Dichloroethene	1.0E-01	b	1.0E-02	b	3,000	blood	decreased hematocrit and hemoglobin	rat	oral-gavage
trans-1,2-Dichloroethene	2.0E-01	b	2.0E-02	a	1000 x 1	blood	increased alkaline phosphatase	mouse	oral-drinking water
1,1-Dichloroethene	9.0E-03	b	9.0E-03	a	1,000	liver	lesions	rat	oral-water
Methylene chloride	6.0E-02	b	6.0E-02	a	100 x 1	liver	hepatotoxicity	rat	oral-water
Styrene	3.0E+00	b	2.0E-01	a	1000 x 1	blood. liver	red blood cell effects, increased liver iron	dogs	oral-gavage
Tetrachloroethene	1.0E-01	b	1.0E-02	a	1000 x 1	liver	hepatotoxicity	mouse	oral-gavage
Toluene	2.0E+00	b	2.0E-01	a	1000 x 1	liver,kidney	organ weight changes	rat	oral-gavage
1,1,1-Trichloroethane									
Trichloroethene									
Vinyl chloride									
Xylene	2.0E+00	c	2.0E+00	a	100 x 1	CNS	hyperactivity; lowered body weight	rat	oral-gavage
Metals									
Barium	7.0E-02	b	7.0E-02	a	3	cardiovascular system	increased blood pressure	human	oral - water
Cadmium	5E-4 water/1E-3 food	b	5E-4 water/1E-3 food	a	10	kidney	proteinuria	human	modeled - diet
Chromium	2.0E-02	b	5.0E-03	a	500	NA	no observed effect	rat	oral-water
Iron									
Lead									
Manganese	5E-3 water/1.4E-1 food	b	5E-3 water/1.4E-1 food	a	1 x 1	CNS	effects	human	oral-water, diet
Nickel	2.0E-02	b	2.0E-02	b	300	whole body	decrease weight	rat	oral-diet
Selenium	5.0E-03	b	5.0E-03	a	3	whole body	selenosis	human	epidemiology
Silver	5.0E-03	b	5.0E-03	a	3	whole body	argyria	human	l.v.
PHCs									

NOTES:

1. Sources:
   a. US EPA Integrated Risk Information System (IRIS), National Library of Medicine, TOXNET Computer Communications Service, July 1995.
   b. US EPA, Health Effects Summary Tables (HEAST), Office of Solid Waste and Emergency Response/Office of Emergency and Remedial Response, Annual FY 1994.
   c. To be conservative, in the absence of an agency approved subchronic RfD, the chronic value was used.

   A blank space indicates no data found.

2. Chromium VI was used for chromium, total.

4. CNS=Central nervous system; MF= Modifying Factor; UF= Uncertainty Factor; NA= Not Applicable.

TABLE B.8

SUMMARY OF DOSE-RESPONSE INFORMATION - NONCARCINOGENIC EFFECTS - INHALATION
Digital Equipment Corporation
San German, Puerto Rico

Contaminant	Inhalation Subchronic Reference Concentration (mg/m³)		Inhalation Chronic Reference Concentration (mg/m³)		Target Organ/System	Critical Effect	Study Animal	Study Method
Volatile Organic Compounds								
Chloroform								
1,1-Dichloroethane	5.0E+00	b	5.0E-01	b	kidney	damage	rat	inhalation
1,2-Dichloroethane								
cis-1,2-Dichloroethene								
trans-1,2-Dichloroethene								
1,1-Dichloroethene			5.0E-03	c				
Methylene chloride	3.0E+00	b	3.0E+00	b	liver	hepatotoxicity	rat	inhalation
Styrene	1.0E+00	d	1.0E+00	a	CNS	decreased intellectual function	human	occup'l. inhal'n.
Tetrachloroethene	4.6E+00	d	4.6E+00	b				
Toluene	4.0E-01	c,d	4.0E-01	a	CNS	neurological effects	human	occup'l. inhal'n.
1,1,1-Trichloroethane			1.0E+00	c				
Trichloroethene			1.8E-01	c				
Vinyl chloride								
Xylene			3.0E-01	c				
Metals								
Barium	5.0E-03	b	5.0E-04	b	fetus	fetotoxicity	rat	inhalation
Cadmium								
Chromium								
Iron								
Lead	1.5E-03	b	1.5E-03	b				
Manganese	5.0E-05	d	5.0E-05	a	CNS	impairment of neurobehavioral function	human	occup'l. inhal'n.
Nickel								
Selenium								
Silver								
PHCs								
Surrogates								
1,2 Dichloroethene (total)	1.1E+00	e	1.1E+00	e				

NOTES:

Sources:

a. US EPA Integrated Risk Information System (IRIS), National Library of Medicine, TOXNET Computer Communications Service, July 1995.
b. US EPA, Health Effects Summary Tables (HEAST), Office of Solid Waste and Emergency Response/Office of Emergency and Remedial Response, Annual FY 1994
c. HEAST 1994 reports that a subchronic value is available from the Superfund Health Risk Technical Support Center. However, the value will not be released for another month.
d. To be conservative, in the absence of an agency approved subchronic RfC, the chronic value was used.
e. Values developed by Massachusetts Department of Environmental Protection, Office of Research and Standards, 1992.

A blank space indicates no data found.

2. CNS = Central nervous system.

TABLE B.9

SUMMARY OF DOSE-RESPONSE INFORMATION - CARCINOGENIC EFFECTS
Digital Equipment Corporation
San German, Puerto Rico

Contaminant	Weight of Evidence Class	Oral Cancer Slope Factor (mg/kg/day)$^{-1}$	Target Organ/System (oral)	Study Animal	Study Method	Inhalation Cancer Slope Factor (mg/kg/day)$^{-1}$	Inhalation Unit Risk ($\mu g/m^3$)$^{-1}$	Target Organ/System (Inhalation)	Study Animal	Study Method
Volatile Organic Compounds										
Chloroform	B2 a	6.1E-03 a	kidney	rat	oral-drinking water	8.1E-02 b	2.3E-05 a	liver	mouse	oral-gavage
1,1-Dichloroethene	C a									
1,2-Dichloroethane	B2 a	9.1E-02 a	blood	rat, mouse	oral-gavage	9.1E-02 b	2.6E-05 a	lung	mouse	topical application
cis,-1,2-Dichloroethene	D a									
trans-1,2-Dichloroethene										
1,1-Dichloroethene	C a	6.0E-01 a	adrenal gland	mouse	inhalation	1.2E+00 b	5.0E-05 a	kidney	mouse	inhalation
Methylene chloride	B2 a	7.5E-03 a	liver	mouse	oral-water		4.7E-07 a	lung; liver	mouse	inhalation
Styrene										
Tetrachloroethene	B2-C c	5.2E-02 a				2.0E-03 c	5.8E-07 c			
Toluene	D a									
1,1,1-Trichloroethane	D a									
Trichloroethene		1.1E-02 c				6.0E-03 c	1.7E-06 c			
Vinyl chloride	A b	1.9E+00 b	lung, liver	rat	oral-diet	3.0E-01 b	8.4E-05 b	liver	rat	inhalation
Xylene	D a									
Metals										
Barium										
Cadmium	B1 a					6.1E+0 b	1.8E-3 a	lung, trachea, bronchus	human	occupat'l. inhal'n.
Chromium	A a					4.1E+1 b	1.2E-2 a	lung	human	occupat'l. inhal'n.
Iron										
Lead	B2 a									
Manganese	D a									
Nickel	A a					8.4E-1 b	2.4E-4 a	lung	human	occupat'l. inhal'n.
Selenium	D a									
Silver	D a									
PHCs										

Notes:

1. Sources:
   a. US EPA, Integrated Risk Information System (IRIS). National Library of Medicine TOXNET Computer Communication Service, July 1995.
   b. US EPA, Health Effects Summary Tables (HEAST), Office of Solid Waste and Emergency Response/Office of Emergency and Remedial Response. Annual FY 1994, March 1994 and updates from Supplements No. 1 and No. 2.
   c. USEPA ORD Scripts for Carcinogenicity Questions on Tetrachloroethylene and Trichloroethylene. 1992.

2. Weight of evidence classification:
   - A: Human carcinogen
   - B: Probable human carcinogen
     - B1: Limited evidence of carcinogenicity in humans from epidemiological studies
     - B2: Sufficient evidence of carcinogenicity in animals, inadequate evidence in humans
   - C: Possible human carcinogen
   - D: Not classified
   - E: No evidence of carcinogenicity

3. Inhalation unit risk is defined as the risk per concentration unit in air, e.g. risk per $\mu g/m^3$.

TABLE B.10

ABSORPTION ADJUSTMENT FACTORS
Digital Equipment Corporation
San German, Puerto Rico

Contaminant	Exposure Pathways									
	Oral Water		Oral Diet		Oral Soil/Sediment		Dermal Water		Dermal Soil/Sediment	
	Carcinogen	Non-Carcinogen	Carcinogen	Non-Carcinogen	Carcinogen	Non-Carcinogen	Carcinogen	Non-Carcinogen	Carcinogen	Non-Carcinogen
Volatile Organic Compounds										
Chloroform	1.00 a	1.00 a	1.00 a	1.00 a	1.00 a	1.00 a	1.00 b	1.00 b	0.10 a	0.10 a
1,1-Dichloroethane		1.30 a		1.30 a		1.30 a		1.30 b		0.13 a
1,2-Dichloroethane	1.00 a	1.00 a	1.00 a	1.00 a	1.00 a	1.00 a	1.00 b	1.00 b	0.10 a	0.10 a
cis,-1,2-Dichloroethene		1.00 a		1.00 a		1.00 a		1.00 b		0.10 a
trans-1,2-Dichloroethene		1.00 a		1.00 a		1.00 a		1.00 b		0.10 a
1,1-Dichloroethene	1.02 a	1.00 a	1.02 a	1.00 a	1.02 a	1.00 a	1.02 b	1.00 b	0.102 a	0.10 a
Methylene chloride	1.00 a	1.00 a	1.00 a	1.00 a	1.00 a	1.00 a	1.00 b	1.00 b	0.10 a	0.10 a
Styrene										
Tetrachloroethene	1.00 a	1.00 a	1.00 a	1.00 a	1.00 a	1.00 a	1.00 b	1.00 b	0.10 a	0.10 a
Toluene		1.00 a		1.00 a		1.00 a		1.00 b		0.12 a
1,1,1-Trichloroethane		1.00 a		1.00 a		1.00 a		1.00 b		0.10 a
Trichloroethene	1.00 a	1.00 a	1.00 a	1.00 a	1.00 a	1.00 a		1.00 b	0.10 a	0.10 a
Vinyl chloride	1.00 b	1.00 a	1.00 b	1.00 a	1.00 b	1.00 a	1.00 b	1.00 b		0.10 a
Xylene		1.00 a		1.00 a		1.00 a		1.00 b		0.12 a
Metals										
Barium		1.00 b		1.00 b		1.00 b		1.00 b		0.01 b
Cadmium		1.00 b		1.00 b		1.00 b		40.00 b		0.40 b
Chromium		1.00 a		1.00 a		1.00 a		9.00 b		0.09 a
Iron										
Lead		0.50 a		0.50 a		0.50 a		1.00 b		0.006 a
Manganese		1.00 b		1.00 b		1.00 b		2.50 b		0.25 b
Nickel		1.00 a		1.00 a		1.00 a		10.00 b		0.35 a
Selenium		1.00 b		1.00 b		1.00 b		1.00 b		0.01 b
Silver		1.00 a		1.00 a		1.00 a		0.25 b		0.25 a
PHCs										

Notes:
a - Values obtained from MA DEP Documentation for the Risk Assessment Short Form Residential Scenario.
b - GZA derived values.

TABLE B.13

PATHWAY - SPECIFIC CONCENTRATION LIMITS FOR SOIL
(Based on Utility Worker Dermal Contact and Incidental Ingestion Exposure to Soil - Noncarcinongenic Effects)
Digital Equipment Corporation
San German, Puerto Rico

Target Organ: Blood Effects
Contaminants: Cis 1,2-Dichloroethene and Trans 1,2-Dichloroethene
Target Hazard Index (THI) for each target organ/system = 1

Pathway - Specific Concentration Limits for Soil (for each contaminant) = THI/2 * RfD/[(EFdc * AAFdc) + (EFii * AAFii)]

Parameters for cis 1,2-Dichloroethene:

Subchronic RfD =	1.0E-01	mg/kg-day
Oral Soil AAF (AAFii) =	1.00	
Dermal Soil AAF (AAFdc) =	0.10	
Receptor-Specific Exposure Factor for Incidental Ingestion (EFii) =	9.4E-08	kg/kg-day
Receptor-Specific Exposure Factor for Dermal Contact (EFdc) =	2.0E-06	kg/kg-day

Pathway - Specific Concentration Limit in Soil for cis 1,2-Dichloroethene: 171,247 mg/kg

Parameters for trans 1,2-Dichloroethene:

Subchronic RfD =	2.0E-01	mg/kg-day
Oral Soil AAF (AAFii) =	1.00	
Dermal Soil AAF (AAFdc) =	0.10	
Receptor-Specific Exposure Factor for Incidental Ingestion (EFii) =	9.4E-08	kg/kg-day
Receptor-Specific Exposure Factor for Dermal Contact (EFdc) =	2.0E-06	kg/kg-day

Pathway - Specific Concentration Limit in Soil for trans 1,2-Dichloroethene: 342,493 mg/kg

TABLE B.13 (Continued)

PATHWAY - SPECIFIC CONCENTRATION LIMITS FOR SOIL
(Based on Utility Worker Dermal Contact and Incidental Ingestion Exposure to Soil - Carcinongenic Effects)
Digital Equipment Corporation
San German, Puerto Rico

Contaminants: Trichloroethene
Target Risk (TR) = 1.0E-06

Pathway - Specific Concentration Limit for Soil (for each contaminant) = TR/{CSF* [(EFdc * AAFdc) + (EFii * AAFii)]}

Parameters for Trichloroethene:

Oral Cancer Slope Factor =	1.1E-02	$(mg/kg\text{-}day)^{-1}$
Oral Soil AAF (AAFii) =	1.00	
Dermal Soil AAF (AAFdc) =	0.10	
Receptor-Specific Exposure Factor for Incidental Ingestion (EFii) =	1.3E-09	(kg/kg-day)
Receptor-Specific Exposure Factor for Dermal Contact (EFdc) =	2.8E-08	(kg/kg-day)
Pathway - Specific Concentration Limit for Soil for Trichloroethene:	**21,795**	mg/kg

TABLE B.14

PATHWAY - SPECIFIC CONCENTRATION LIMITS FOR GROUNDWATER
(Based on Utility Worker Dermal Contact Exposure to Groundwater)
Digital Equipment Corporation
San German, Puerto Rico

NONCARCINOGENIC EFFECTS

Target Organ	Contaminant	Target Hazard Index	x	Subchronic RfD (mg/kg-day)	=	Target Dose (mg/kg-day)	/	Dermal AAF	/	Receptor-Specific Exposure Factor (l-hr/cm-kg-day)	/	Kp (cm/hour)	=	PSCLs (mg/l)
Liver	Chloroform	0.5		1.0E-02		5.0E-03		1.00		2.9E-03		1.0E-01		17
	1,1-Dichloroethene	0.5		9.0E-03		4.5E-03		1.00		2.9E-03		1.6E-02		98
	Subtotal:													
Blood	Cis1,2-Dichloroethene	1.0		1.0E-01		1.0E-01		1.00		2.9E-03		1.0E-02		3,471
Other	1,1-Dichloroethane	1.0		1.0E+00		1.0E+00		1.33		2.9E-03		8.9E-03		29,327

CARCINOGENIC EFFECTS

Contaminant	Target Risk Level	/	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	=	Target Dose (mg/kg-day)	/	Dermal AAF	/	Receptor-Specific Exposure Factor (l-hr/cm-kg-day)	/	Kp (cm/hour)	=	PSCLs (mg/l)
Chloroform	1.0E-06		6.1E-03		1.6E-04		1.00		4.1E-05		1.0E-01		40
Trichloroethene	1.0E-06		1.1E-02		9.1E-05		1.00		4.1E-05		2.0E-01		11
1,2-Dichloroethane	1.0E-06		9.1E-02		1.1E-05		1.00		4.1E-05		5.3E-03		50
1,1-Dichloroethene	1.0E-06		6.0E-01		1.7E-06		1.02		4.1E-05		1.6E-02		2.5

Notes:

1. Contaminants for which Pathway - Specific Concentration Limits (PSCLs) were calculated were based on contaminants detected in groundwater collected from monitoring wells at the site in November 1994 where depth to groundwater based on measurements made between November 1994 and January 1995, is 0 to 8 feet below groundwater surface (i.e., OW-2, OW-103, OW-105, OW-106, OW-303A, OW-305, and OW-404U).

2. A default dermal water AAF of 1.0 was used for TCE.

3. NA = Not Available, NC = Not Calculated.

APPENDIX B-1

EVALUATION OF POTENTIAL RISKS FOR FACILITY WORKERS ASSOCIATED WITH INHALATION OF VOC VAPORS IN INDOOR AIR

APPENDIX B-1

EVALUATION OF POTENTIAL RISKS FOR FACILITY WORKERS ASSOCIATED WITH INHALATION OF VOC VAPORS IN INDOOR AIR

1.00 INTRODUCTION

Two different source media may contribute VOC vapors to indoor air within site buildings (i.e., soil gas beneath Buildings 1 and 2 and use of groundwater as a source of process water at the facility). Facility workers employed in site buildings may inhale VOC vapors in indoor air. To calculate Media Protection Standards (MPS) in groundwater which will be protective of potential inhalation exposures for these workers, it was necessary to determine the relative contribution of each of these sources to the total risk for the facility worker (assuming that the source of soil gas is associated with contaminants in groundwater). Therefore, using "forward" risk assessment calculations, we calculated hazard indices (HIs) and cancer risk estimates based on estimated indoor air exposure point concentrations (EPCs) associated with: (1) VOCs in soil gas beneath Buildings 1 and 2, and (2) VOCs in site groundwater which is used as process water at the facility.

HIs and cancer risk estimates for facility workers were calculated by combining estimated indoor air EPCs with chemical-specific toxicity information (i.e., reference concentrations and inhalation unit risks) and assumptions regarding exposure (i.e. exposure factors). Receptor-specific exposure factors for the facility worker, for chronic noncarcinogenic effects and carcinogenic effects, are presented in Table B.5. Toxicity information for contaminants detected in process water from pumping wells and in soil gas beneath the Buildings 1 and 2 is summarized in Tables B.7 through B.9.

2.00 EXPOSURE POINT CONCENTRATIONS

2.10 Process Water

Concentrations of contaminants (i.e., cis 1,2-dichloroethene and trichloroethene) detected in groundwater sample "Influent", collected on December 2, 1994, were used to estimate indoor air EPCs (refer to Attachment 1). Estimated indoor air EPCs for cis 1,2-dichloroethene (cis 1,2-DCE) and trichloroethene (TCE) were combined with assumptions regarding exposure (refer to Table B.5) and chemical-specific toxicity information (refer to Tables B.7 through B.9) to evaluate potential risks for facility workers who may inhale VOC vapors in indoor associated with use of groundwater as process water in the facility (refer to Table B-1.2).

2.20 Soil Gas

The 95th percent upper confidence limit (UCL) of the arithmetic mean soil gas concentrations beneath the Buildings 1 and 2 were incorporated into a model (Johnson & Ettinger, 1991) to estimate indoor air concentrations of VOCs (refer to Attachment 2). Table B-1.1 presents a summary of the soil gas analytical data. Estimated indoor air concentrations in the buildings were used to represent EPCs to evaluate potential risks to facility workers associated with inhalation of VOC vapors from soil gas beneath the site buildings.

3.00 CALCULATION OF HAZARD INDICES AND CANCER RISK ESTIMATES

3.10 Estimation of Hazard Indices

The potential for estimated concentrations of VOCs in indoor air to cause noncarcingenic effects for facility workers was evaluated by calculating an average daily exposure (ADE) for each contaminant and comparing it to a chronic reference concentration (RfC). The ADE (ug/m^3) is calculated as the product of the indoor air EPC (ug/m^3) and exposure factor (unitless) for noncarcinogenic effects. The ratio of the ADE to the RfC represents a Hazard Index (HI) which is used to evaluate the potential for an adverse noncancer effect to occur at a given exposure. This relationship may be expressed as follows:

$$HI = ADE\ (ug/m^3)/RfC(ug/m^3)$$

where,

HI = Hazard Index

ADE = Average Daily Exposure (ug/m^3) = Indoor Air EPC (ug/m^3) * Exposure Factor (unitless)

RfC = Reference Concentration (ug/m^3)

HIs were summed by target organ and compared to an acceptable HI of 1.0 per target organ. If the HI is less than 1.0, then no adverse health effects are expected to occur, even in sensitive subpopulations. If the HI exceeds 1.0, then there is cause for concern. However, an HI greater than 1.0 does not indicate that adverse health effects will occur.

Estimation of Cancer Risk Estimates

The excess lifetime cancer risk (ELCR) from exposure to VOCs in indoor air by facility workers was evaluated by calculating a lifetime average daily exposure (LADE) for

each contaminant and comparing it to an inhalation unit risk. The LADE (ug/m^3) is calculated as the product of the indoor air EPC (ug/m^3) and exposure factor (unitless) for carcinogenic effects. The ELCR is calculated as the product of the LADE and the inhalation unit risk. The ELCR is an estimate of the risk of getting cancer over and above the background cancer rate, over a lifetime. This ELCR equation is expressed as follows:

ELCR = inhalation unit risk $(ug/m^3)^{-1}$ * LADE (ug/m^3)

where,

ELCR = Excess Lifetime Cancer Risk Estimate

LADE = Lifetime Average Daily Exposure (ug/m^3)

For potential carcinogenic effects, EPA's target risk range is 10^{-6} to 10^{-4}. This corresponds to a lifetime probability of one in one million to one in one hundred thousand of getting cancer over and above the background rate.

Tables B-1.2 and B-1.3 present HIs and ELCR estimates for the facility worker. The HI and ELCR estimate for inhalation of VOCs in indoor air associated with use of groundwater as process water are 0.006 (other effects) and 5.4×10^{-7}, respectively. The HIs for inhalation of VOCs in indoor air associated with VOCs in soil gas beneath Buildings 1 and 2 are 0.00002 for kidney effects, 0.000002 for liver effects, and 0.002 for other effects. The ELCR estimate for inhalation of VOCs in indoor air associated with VOCs in soil gas beneath Buildings 1 and 2 is 1.7×10^{-7}.

Based on the results of these analyses, potential noncarcinogenic health effects and cancer risks from migration of VOCs in soil gas to indoor air contributes a negligible amount to the total inhalation risk for a facility worker. Therefore, PSCLs in groundwater, which are protective of facility worker inhalation exposure to VOCs in indoor air, were based on an HI of 1.0 and a cancer risk of 1×10^{-6}.

TABLE B-1.1

SUMMARY OF ANALYTICAL SOIL GAS SAMPLES (ppm)
Digital Equipment Corporation
San German, Puerto Rico

Contaminant	Frequency of Detection	Range Detected	Location of Maximum Detected Concentration	95 % UCL Concentration
Volatile Organic Compounds				
1,1-Dichloroethene	10 / 33	0.25 - 3.8	SGI-15	0.283
cis 1,2-Dichloroethene	10 / 33	0.25 - 6.55	SG-102	0.667
1,1,1-Trichloroethane	6 / 33	0.25 - 12	SG-123	0.562
Trichloroethene	15 / 33	0.25 - 15	SGI-25	1.616
Tetrachloroethene	8 / 33	0.25 - 37.5	SG-102	1.120
m,p-Xylenes	1 / 17	1.105 - 1.105	SG-102	0.214
1,1-Dichloroethane	1 / 16	2.6 - 2.6	SGI-15	0.316
Methylene Chloride	2 / 16	0.5 - 0.5	SGI-19, SGI-28	0.212

Notes:

1. For the purpose of calculating arithmetic mean concentrations, one-half the method detection limit was used to represent the concentrations of constituents reported as non-detects (ND), and one time the method detection limit was used to represent the concentrations of constituents reported as "BMQL".

2. Analytical results were based on samples: SGI-15, SGI-16, SGI-17, SGI-18, SGI-19, SGI-20, SGI-21, SGI-22, SGI-23, SGI-24, SGI-25, SGI-26, SGI-27, SGI-28, SGI-29, SGI-30, SG-101, SG-102, SG-103, SG-104, SG-105, SG-106, SG-107, SG-108, SG-120, SG-121, SG-122, SG-123, SG-124, SG-125, SG-126, SG-143, and SG-144, collected between August 1992 and April 1993.

TABLE B-1.2

CALCULATION OF AVERAGE DAILY EXPOSURES AND RISK ESTIMATES
FOR INHALATION OF VAPORS IN INDOOR AIR WITHIN THE SITE BUILDING
SOURCE: PROCESS WATER

RECEPTOR: Facility Worker
CHRONIC NONCARCINOGENIC EFFECTS

Target Organ	Contaminant	Exposure Point Concentration [OHM]air (ug/m^3)	x	Receptor-Specific Exposure Factor (unitless)	=	Chronic Average Daily Exposure (ug/m^3)	/	Inhalation Chronic Reference Concentration (ug/m^3)	=	Hazard Index
Other	Cis 1,2-Dichloroethene	3.3		2.3E-01		7.5E-01		1100		0.0007
	Trichloroethene	3.9		2.3E-01		8.9E-01		180		0.005
								Subtotal:		0.006

RECEPTOR: Facility Worker
CARCINOGENIC EFFECTS

Contaminant	Exposure Point Concentration [OHM]air (ug/m^3)	x	Receptor-Specific Exposure Factor (unitless)	=	Lifetime Average Daily Exposure (ug/m^3)	x	Inhalation Unit Risk $(ug/m^3)^{-1}$	=	Excess Lifetime Cancer Risk Estimate
Cis 1,2-Dichloroethene	3.3		8.2E-02		2.7E-01		NA		NC
Trichloroethene	3.9		8.2E-02		3.2E-01		1.7E-06		5.4E-07
							SUBTOTAL:		5.4E-07

Notes:

1. NA = Not Analyzed/Not Applicable; NC = Not Calculated; ND = Not Determined.

2. In the absence of an agency approved inhalation chronic RfC for cis 1,2-DCE, we used the inhalation chronic RfC for 1,2-DCE (total) (i.e., 1100 ug/m^3), developed by the Massachusetts Department of Environmental Protection, Office of Research and Standards, October 1992.

3. In the absence of an agency approved inhalation chronic RfC for TCE, we used the inhalation chronic RfC for TCE developed by the Massachusetts Department of Environmental Protection, Office of Research and Standards, 1992.

TABLE B-13

CALCULATION OF AVERAGE DAILY EXPOSURES AND RISK ESTIMATES FOR INHALATION OF VAPORS IN INDOOR AIR WITHIN THE SITE BUILDING SOURCE: SOIL GAS

RECEPTOR: Facility Worker
CHRONIC NONCARCINOGENIC EFFECTS

Target Organ	Contaminant	Exposure Point Concentration [OHM]air ($\mu g/m^3$)	x	Receptor-Specific Exposure Factor (unitless)	=	Chronic Average Daily Exposure ($\mu g/m^3$)	/	Inhalation Chronic Reference Concentration ($\mu g/m^3$)	=	Hazard Index
Kidney	1,1-Dichloroethane	0.035		2.3E-01		8.0E-03		500		0.00002
Liver	Methylene Chloride	0.020		2.3E-01		4.6E-03		3000		0.000002
Other	1,1-Dichloroethene	0.031		2.3E-01		7.0E-03		5		0.001
	cis-1,2-Dichloroethene	0.072		2.3E-01		1.7E-02		NA		NC
	Tetrachloroethene	0.208		2.3E-01		4.7E-02		4600		0.00001
	1,1,1-Trichloroethane	0.084		2.3E-01		1.9E-02		1000		0.00002
	Trichloroethene	0.237		2.3E-01		5.4E-02		180		0.0003
	m,p-Xylene	0.025		2.3E-01		5.8E-03		300		0.00002
								Subtotal:		0.002

RECEPTOR: Facility Worker
CARCINOGENIC EFFECTS

Contaminant	Exposure Point Concentration [OHM]air ($\mu g/m^3$)	x	Receptor-Specific Exposure Factor (unitless)	=	Lifetime Average Daily Exposure ($\mu g/m^3$)	x	Inhalation Unit Risk $(\mu g/m^3)^{-1}$	=	Excess Lifetime Cancer Risk Estimate
1,1-Dichoroethane	0.035		8.2E-02		2.9E-03		NA		NC
1,1-Dichloroethene	0.031		8.2E-02		2.5E-03		5.0E-05		1.3E-07
cis-1,2-Dichloroethene	0.072		8.2E-02		5.9E-03		NA		NC
Methylene Chloride	0.020		8.2E-02		1.6E-03		4.7E-07		7.7E-10
Tetrachloroethene	0.208		8.2E-02		1.7E-02		5.8E-07		9.8E-09
1,1,1-Trichloroethane	0.084		8.2E-02		6.8E-03		NA		NC
Trichloroethene	0.237		8.2E-02		1.9E-02		1.7E-06		3.3E-08
m,p-Xylene	0.025		8.2E-02		2.1E-03		NA		NC
							SUBTOTAL:		1.7E-07

Notes:

1. NA = Not Available/Not Applicable; NC = Not Calculated.

2. In the absence of agency approved inhalation chronic RfCs for 1,1-DCE, 1,1,1-TCA,TCE, and m,p-xylene, we used the inhalation chronic RfCs for these compounds developed by the Massachusetts Department of Environmental Protection, Office of Research and Standards, 1992.

CALCULATION OF EFFECTIVE POROUS MEDIA DIFFUSION COEFFICIENT
Digital Equipment Corporation
San German, Puerto Rico

Contaminant	Dry Soil Bulk Density (g/cm^3)	Total Porosity	Moisture Content (g H20/g soil)	Moisture Filled Porosity	Vapor Filled Porosity	Molecular Diffusivity in Air (cm^2/s)	Vapor Porous Media Diffusion Coeff. (cm^2/s)	Molecular Diffusivity in Water (cm^2/s)	Water Porous Media Diffusion Coeff. (cm^2/s)	"Overall" Effective Porous Media Diffusion Coeff. (cm^2/s)
	[illegible]	[illegible]	[illegible]	Em	Ev	[illegible]	Dv	[illegible]	Dm	Dt
1,1-Dichloroethene	1.7	0.38	0.07	0.16	0.22	8.80E-02	3.94E-03	9.80E-06	1.52E-07	3.94E-03
cis 1,2-Dichloroethene	1.7	0.38	0.07	0.16	0.22	8.80E-02	3.94E-03	9.80E-06	1.52E-07	3.94E-03
1,1,1-Trichloroethane	1.7	0.38	0.07	0.16	0.22	7.80E-02	3.49E-03	8.80E-06	1.36E-07	3.49E-03
Trichloroethene	1.7	0.38	0.07	0.16	0.22	7.90E-02	3.53E-03	9.10E-06	1.41E-07	3.53E-03
Tetrachloroethene	1.7	0.38	0.07	0.16	0.22	7.20E-02	3.22E-03	8.20E-06	1.27E-07	3.22E-03
m,p-Xylenes	1.7	0.38	0.07	0.16	0.22	7.00E-02	3.13E-03	7.80E-06	1.21E-07	3.13E-03
1,1-Dichloroethane	1.7	0.38	0.07	0.16	0.22	8.80E-02	3.94E-03	9.80E-06	1.52E-07	3.94E-03
Methylene Chloride	1.7	0.38	0.07	0.16	0.22	1.01E-01	4.52E-03	1.17E-05	1.81E-07	4.52E-03

Notes (for input parameters only):

(1) Dry soil bulk density: for dense, mixed grain sand = 1.7 g/cm^3 (Reference: Peck, Hanson, Thornburn, Foundation Engineering, Table 1.4, Porosity, Void Ratio, and Unit Weight of Typical Soils in Natural State).

(2) Total porosity: for dense, mixed grain sand = 0.38 (Reference: Peck, Hanson, Thornburn, Foundation Engineering, Table 1.4, Porosity, Void Ratio, an Unit Weight of) Typical Soils in Natural State).

(3) Moisture content: for sand (reference: Johnson and Ettinger, 1991).

(4) Molecular Diffusivity in Air (@ 10 degrees Celsius): contaminant-specific (Reference: USEPA 1990, Hazardous Waste Treatment, Storage, and Disposal Facilities (TSDF) - Air Emission Models, ChemDat7 Database, Appendix D)

(5) Molecular Diffusivity in Water: contaminant-specific (Reference: USEPA 1990, Hazardous Waste Treatment, Storage, and Disposal Facilities (TSDF) - Air Emission Models, ChemDat7 Database, Appendix D)

CALCULATION OF VOLUMETRIC FLOW RATE OF SOIL GAS INTO THE BUILDING
Digital Equipment Corporation
San German, Puerto Rico

Contaminant	Foundation Soil Contact Area (m^2)	Acr/Ab	Basement Crack Area (m^2)	Total Basement Crack Length (m)	Radius of Basement Crack (cm)	Depth from Ground Surface to Crack (m)	Pressure Difference Source to Indoor Air 1 Pa = 10 g/cm-s^2 (Pa)	Soil Intrinsic Permeability (cm^2)	Vapor Dynamic Viscosity (g/cm-s)	Volumetric Flow Rate of Soil Gas into Building (cm^3/s)
	Ab	n	Acr	XCr	r_cr	Z	dP	k	u	Qsoil
1,1-Dichloroethene	8,250	0.001	8 250	370.0	1.1	1.0	1	1.0E-07	1.8E-04	2.9E+02
cis 1,2-Dichloroethene	8,250	0.001	8 250	370 0	1.1	1.0	1	1 0E-07	1.8E-04	2.9E+02
1,1,1-Trichloroethane	8,250	0.001	8,250	370.0	1.1	1.0	1	1.0E-07	1.8E-04	2.9E+02
Trichloroethene	8,250	0.001	8.250	370.0	1.1	1.0	1	1.0E-07	1.8E-04	2.9E+02
Tetrachloroethene	8,250	0.001	8,250	370.0	1.1	1.0	1	1.0E-07	1.8E-04	2.9E+02
m,p-Xylenes	8,250	0.001	8.250	370.0	1.1	1.0	1	1.0E-07	1.8E-04	2.9E+02
1,1-Dichloroethane	8,250	0.001	8.250	370.0	1.1	1.0	1	1.0E-07	1.8E-04	2.9E+02
Methylene Chloride	8,250	0.001	8.250	370.0	1.1	1.0	1	1.0E-07	1.8E-04	2.9E+02

Notes (for input parameters only):

(1) Foundation Soil Contact Area (the cross-sectional area through which vapors pass)

(2) n = Acr/Ab: default

(3) Total Basement Crack Length (the total floor/wall seam perimeter distance)

Total basement crack length for site building = approximate perimeter of the building

(4) Depth from Ground Surface to Crack: 1 meter

(5) Pressure Difference (Source to Indoor Air): 1 Pa (reference: Johnson and Ettinger, 1991).

(6) Soil Intrinsic Permeability: for sand = 1.0E-07 (Reference: The New SESOIL User's Guide, Chapter 4 (Building the SESOIL Model Inputs in RISKPRO), Table 4.3, Default values of the intrinsic permeability (Bonazountas and Wagner, 1984))

CALCULATION OF CONTAMINANT-SPECIFIC ATTENUATION FACTORS
Digital Equipment Corporation
San German, Puerto Rico

Contaminant	"Overall" Effective Porous Media Diffusion Coeff. (cm^2/s)	Foundation Soil Contact Area (m^2)	Basement or Building Ventilation Rate (cm^3/s)	Distance from Contaminant Source to Foundation (cm)	Volumetric Flow Rate of Soil Gas into Building (cm^3/s)	Foundation Thickness (cm)	Effective Vapor-Pressure Diffusion Coefficient Through the Crack (cm^2/s)	Acr/Ab	Basement Crack Area (m^2)	Advective-Dominated Constant "Effective Peclet" Number	Diffusion Dominated Constant	Qsoil/ Qbuilding	Measured Soil Gas Concentration Under Slab (ppmv)	Gram Molecular Weight (g/mole)	Converted Soil Gas Concentration (ug/m^3)	Calculated Indoor Air Concentration In Building (ug/m^3)
	Di	Ab	[illegible]	[illegible]	Qsoil	[illegible]	Dcr	n	Acr	A	B	C	Cppmv	MW	Csoil	Cbuild
1,1-Dichloroethene	3.94E-03	8250.0	11,458.333	670	2.9E+02	20.32	3.94E-03	0.001	8.250	17.97	4.23E-05	2.51E-05	0.283	97.0	1226.35	0.031
cis 1,2-Dichloroethene	3.94E-03	8250.0	11,458.333	670	2.9E+02	20.32	3.94E-03	0.001	8.250	17.97	4.23E-05	2.51E-05	0.667	97.0	2888.78	0.072
1,1,1-Trichloroethane	3.49E-03	8250.0	11,458.333	670	2.9E+02	20.32	3.49E-03	0.001	8.250	20.27	3.75E-05	2.51E-05	0.562	133.0	3334.17	0.084
Trichloroethene	3.53E-03	8250.0	11,458.333	670	2.9E+02	20.32	3.53E-03	0.001	8.250	20.02	3.80E-05	2.51E-05	1.616	131.0	9450.38	0.237
Tetrachloroethene	3.22E-03	8250.0	11,458.333	670	2.9E+02	20.32	3.22E-03	0.001	8.250	21.96	3.46E-05	2.51E-05	1.120	166.0	8296.87	0.208
m,p-Xylenes	3.13E-03	8250.0	11,458.333	670	2.9E+02	20.32	3.13E-03	0.001	8.250	22.59	3.37E-05	2.51E-05	0.214	106.0	1014.46	0.025
1,1-Dichloroethane	3.94E-03	8250.0	11,458.333	670	2.9E+02	20.32	3.94E-03	0.001	8.250	17.97	4.23E-05	2.51E-05	0.316	99.0	1396.82	0.035
Methylene Chloride	4.52E-03	8250.0	11,458.333	670	2.9E+02	20.32	4.52E-03	0.001	8.250	15.66	4.86E-05	2.51E-05	0.212	85.0	803.25	0.020

Notes (for input parameters only):

(1) Basement or Building Ventilation Rate: Assuming one-half air change per hour

(2) Distance from Contaminant Source to Foundation: approximately 670 cm based on site boring logs

(3) Foundation Thickness: 8 inches = 20.32 cm

ATTACHMENT 1

EXPOSURE POINT CONCENTRATIONS IN INDOOR AIR BASED ON CONCENTRATIONS DETECTED IN PROCESS WATER

GZA GeoEnvironmental, Inc.
Engineers and Scientists

Page No. 1/1

Project: Digital – San German Puerto Rico — File No. 20876.90
Location — Date — By AMF
Subject: Estimation of Indoor Air Concentrations — Checked By EDS
Based on: Contaminants detected in Process Water — Revised — By

VOLUME OF BUILDING 82,500 m^3 110m x 75m x 10m

PUMPING RATE OF PROCESS WATER 200 GALLONS/MIN

ASSUMED VENTILATION RATE 2 ACH i.e. 165,000 m^3/HR

CONCENTRATION IN PROCESS WATER:

0.012 mg/L c 12 DCE
0.014 mg/L TCE

12 DCE

$$200 \frac{\text{GALLONS}}{\text{MIN}} \times \frac{3.785\ \text{L}}{1\ \text{GAL}} \times \frac{12\ \mu\text{g}}{\text{L}} \times \frac{60\ \text{MIN}}{165{,}000\ m^3} = 3.3\ \mu\text{g}/m^3$$

TCE

$$200 \frac{\text{GALLONS}}{\text{MIN}} \times \frac{3.785\ \text{L}}{1\ \text{GAL}} \times \frac{14\ \mu\text{g}}{\text{L}} \times \frac{60\ \text{MIN}}{165{,}000} = 3.9\ \mu\text{g}/m^3$$

GZA GEOENVIRONMENTAL, INC.
ENVIRONMENTAL CHEMISTRY LABORATORY
320 NEEDHAM STREET, NEWTON UPPER FALLS, MA 02164
MASSACHUSETTS LABORATORY I.D. NO.: MA092

EPA METHOD 8260 ANALYSIS FOR VOLATILE ORGANICS BY GC/MS
CONCENTRATION (PPB–ug/L – Aqueous)

PROJECT:	DIGITAL – SGO – SAN GERMAIN, PR		
FILE NO.:	20876.7	PROJECT MGR.:	J. PAQUIN
SAMPLE ID:	INFLUENT	DATE SAMPLED:	12/2/94
MATRIX:	AQUEOUS	DATE TESTED:	12/7/94
LABORATORY #:	P9072	DILUTION FACTOR:	1

TARGET COMPOUND LIST 8260 COMPOUNDS	CONC.	QUANT. LIMIT	TARGET COMPOUND LIST 8260 COMPOUNDS:	CONC.	QUANT. LIMIT
DICHLORODIFLUOROMETHANE	ND	2	2-HEXANONE (MBK)	ND	2
CHLOROMETHANE	ND	2	1,3-DICHLOROPROPANE	ND	1
VINYL CHLORIDE	ND	2	TETRACHLOROETHENE	ND	1
BROMOMETHANE	ND	2	DIBROMOCHLOROMETHANE	ND	1
CHLOROETHANE	ND	2	1,2-DIBROMOETHANE (EDB)	ND	2
TRICHLOROFLUOROMETHANE	ND	4	CHLOROBENZENE	ND	1
ACETONE	ND	25	1,1,1,2-TETRACHLOROETHANE	ND	1
1,1-DICHLOROETHENE	ND	1	ETHYL BENZENE	ND	1
METHYLENE CHLORIDE	ND	1	m&p-XYLENES	ND	1
CARBON DISULFIDE	ND	2	o-XYLENE	ND	1
METHYL tert-BUTYL ETHER (MtBE)	ND	1	STYRENE	ND	1
trans-1,2-DICHLOROETHENE	ND	1	BROMOFORM	ND	2
1,1-DICHLOROETHANE	ND	1	ISOPROPYLBENZENE	ND	1
VINYL ACETATE	ND	5	1,1,2,2-TETRACHLOROETHANE	NO	1
2-BUTANONE (MEK)	ND	25	1,2,3-TRICHLOROPROPANE	ND	1
2,2-DICHLOROPROPANE	ND	1	BROMOBENZENE	ND	1
cis-1,2-DICHLOROETHENE	--12--	1	n-PROPYLBENZENE	NO	1
CHLOROFORM	ND	1	2-CHLORDTOLUENE	ND	1
BROMOCHLOROMETHANE	ND	1	1,3,5-TRIMETHYLBENZENE	ND	1
1,1,1-TRICHLOROETHANE	ND	1	4-CHLOROTOLUENE	ND	1
1,1-DICHLOROPROPENE	ND	1	tert-BUTYLBENZENE	ND	1
CARBON TETRACHLORIDE	ND	1	1,2,4-TRIMETHYLBENZENE	ND	1
1,2-DICHLOROETHANE	ND	1	sec-BUTYLBENZENE	ND	1
BENZENE	ND	1	p-ISOPROPYLTOLUENE	ND	1
TRICHLOROETHENE	--14--	1	1,3-DICHLOROBENZENE	ND	1
1,2-DICHLOROPROPANE	ND	1	1,4-DICHLOROBENZENE	ND	1
BROMODICHLOROMETHANE	ND	1	n-BUTYLBENZENE	ND	1
DIBROMOMETHANE	ND	1	1,2-DICHLOROBENZENE	ND	1
4-METHYL-2-PENTANONE (MIBK)	ND	1	1,2-DIBROMO-3-CHLOROPROPANE	ND	5
cis-1,3-DICHLOROPROPENE	ND	1	1,2,4-TRICHLOROBENZENE	ND	1
TOLUENE	NO	1	HEXACHLOROBUTADIENE	ND	1
trans-1,3-DICHLOROPROPENE	ND	1	NAPHTHALENE	ND	1
1,1,2-TRICHLOROETHANE	ND	1	1,2,3-TRICHLOROBENZENE	ND	1
SURROGATE	% RECOV.		SURROGATE	% RECOV.	
1,2-DICHLOROETHANE - D4	99.7		TOLUENE - D8	100	

ANALYZED BY: L Wong

REVIEWED BY: K Wall

ATTACHMENT 2

EXPOSURE POINT CONCENTRATIONS IN INDOOR AIR BASED ON CONCENTRATIONS DETECTED IN SOIL GAS

APPENDIX B-1
ATTACHMENT 2

DERIVATION OF INDOOR AIR CONCENTRATIONS BASED ON VAPOR INTRUSION OF SOIL GAS INTO SITE BUILDING

1.00 INTRODUCTION

GZA calculated indoor air concentrations within the site building using an approach developed by Johnson and Ettinger (1991) which relates the indoor air concentration to the soil gas concentration of volatile contaminants at the surface of underlying groundwater. GZA integrated site-specific information (i.e., building size and ventilation rate, soil characteristics, and chemical-specific information including molecular diffusion coefficients through air and water) into this model, along with measured soil gas concentrations to estimate potential indoor air concentrations within the building.

2.00 MODEL FOR ESTIMATING INDOOR AIR CONCENTRATION

The Johnson & Ettinger model used to derive the indoor air concentration considers a mass balance whereby the mass transport rate of contaminants volatilizing from the groundwater under the building is equal to the mass transport rate through a crack in the basement slab, which is also equal to the mass transport rate of air circulating through the building. The mathematical model can be divided into three primary components. The first describes the diffusion of the contaminant from groundwater under the building to soil gas beneath the foundation. The second component models transport from the soil gas into the building, and the third dilutes the mass flow through the crack by the building air exchange rate.

2.10 DIFFUSIVE TRANSPORT FROM THE SOURCE TO SOIL BENEATH THE STRUCTURE

The diffusion of a contaminant from groundwater under the building to the foundation is presented in the following equation (Eq. 11- Johnson & Ettinger) and described graphically in the following Figure 1.

$$E_I = A_B (C_{source} - C_{soil}) D_t/L_t \qquad (11)$$

where,

E_I = the mass-transport rate toward the structure (g/s),
A_B = the cross-sectional area through which the vapors pass (m^2),

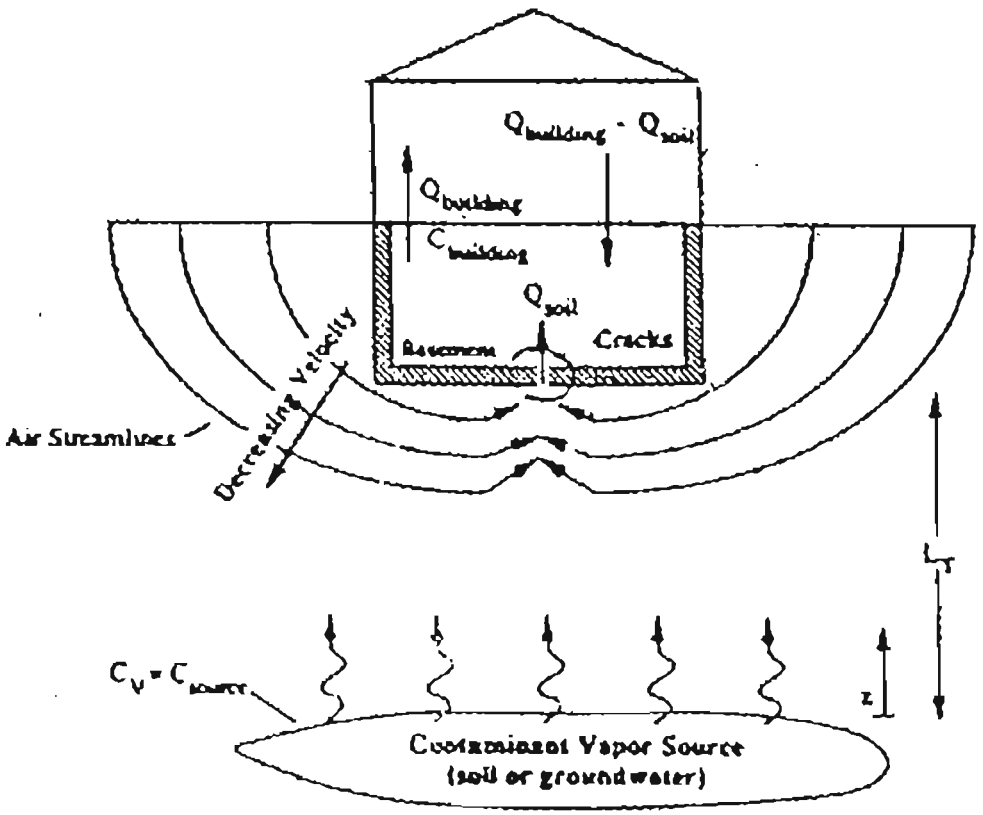

Figure 1. Vapor intrusion scenario.

C_{source} = the vapor concentration at the contaminant source (g/cm^3),
C_{soil} = the vapor concentration beneath the structure (g/cm^3),
L_t = the distance from contaminant source to foundation (cm) and,
D_t = the "overall" effective porous media diffusion coefficient based on vapor phase concentrations for the region between the source and the foundation (cm^2/s).

This is a basic diffusion equation of the type $D^*\delta c/\delta x^*A$, where D is the diffusion coefficient based on the effective value for the contaminant diffusion through unsaturated soil (eq. 4 and 5 - Johnson & Ettinger), $\delta c/\delta x$ is the concentration gradient, and A is the cross-sectional area.

2.20 TRANSPORT FROM SOIL GAS INTO BUILDING

The following equation predicts the entry rate of a contaminant through a crack whereby the concentration under the foundation is C_{soil} and the concentration in the building is $C_{building}$ and constant velocity occurs through the crack. Transport of contaminants from soil gas under a foundation is assumed to occur by a combination of convective and diffusive transport mechanisms. Convection, in this instance, is defined as movement of contaminant mass with the flow of the moving water. Diffusion, in this case, is defined as the movement of contaminant mass due to concentration gradient. The steady-state, one dimensional solution for vapor transport through a crack (or porous medium) with a constant uniform convective velocity (Q_{soil}/A_{crack}) is used to predict the total rate of contaminant intrusion into a building.

$$E_2 = Q_{soil}C_{soil} - [Q_{soil}(C_{soil} - C_{building})/[(1 - \exp (Q_{soil}L_{crack}/D^{crack}A_{crack})]] \quad (14)$$

where,

E_2	=	entry rate of contaminant into the building (g/s)
Q_{soil}	=	volumetric flow rate of soil gas into the building (cm^3/s)
C_{soil}	=	soil gas contaminant concentration (g/cm^3)
$C_{building}$	=	contaminant vapor concentration in the building (g/cm^3)
L_{crack}	=	thickness of the foundation (cm)
D^{crack}	=	effective vapor-pressure diffusion coefficient through the crack (cm^2/s)
A_{crack}	=	area of cracks/openings through which contaminant vapors enter the building (m^2)

2.30 INDOOR CONTAMINANT VAPOR CONCENTRATION

The flux of contaminant entering the building through the crack is diluted only by the ventilation of air exchanged in the building. Assuming no other contaminant sinks (such as walls or furniture),

$$E_3 = Q_{building}\, C_{building} \quad (17)$$

where,

E_3	=	the mass transport rate of contaminant vapors circulating through the building (g/s),
$Q_{building}$	=	the ventilation rate in the basement or building (cm^3/s), and
$C_{building}$	=	the concentration of the contaminant in the vapor in the building (g/cm^3)

The resulting equation for the indoor air concentration ($C_{building}$) considers that

$$E_1 = E_2 = E_3$$

where,

E_1 = the mass-transport rate toward the structure (g/s) (eq. 11)
E_2 = the entry rate of contaminant into the building (g/s) (eq. 14)
E_3 = the flow rate of contaminant in the building air (g/s)(eq. 17)

or that the mass transport rate from the contaminant source is equal to the mass flux of contaminants through the crack into the building which is also equal to the flow rate of contaminants circulating through the building. By equating equations (14) and (17), and solving for $C_{building}$, the relationship between soil gas concentration and indoor air concentration can be described as follows:

$$C_{building} = Q_{soil} (C_{soil} (1-\exp(Q_{soil}L_{crack}/D^{crack}A_{crack}))-C_{soil}/Q_{building} (1-\exp(Q_{soil}L_{crack}/D^{crack}A_{crack}))-Q_{soil}$$

3.00 MODEL PARAMETERS

The intent of this model is to calculate indoor air concentrations using site-specific parameters and detected concentrations of volatile contaminants in soil gas beneath site buildings. Equation parameters and the values used in calculating $C_{building}$ are shown in the attached tables.

3.10 CALCULATION OF EFFECTIVE POROUS MEDIA DIFFUSION COEFFICIENT

The first part of the model calculates the "overall" effective porous media diffusion coefficient (D_t). The input parameters for this part of the calculation are related to the type of soil at the site and the diffusion properties of the contaminants. They are interrelated according to the following relationships.

$$D_t = D^{water}E_m^{3.33}/E_t^2 \qquad (4)$$

where,

D_t = Effective porous medium diffusion coefficient
D^{water} = Molecular diffusivity in water. (cm^2/sec)
E_m = Moisture filled porosity
E_t = Total soil porosity, and

$$D_t = D^{air}E_v^{3.33}/E_t^2 \qquad (5)$$

where,

E_v = Vapor filled porosity
$E_t = (E_v + E_m)$
D^{air} = Molecular diffusivity in air (cm^2/sec)
D_t = Effective porous medium diffusion coefficient

APPENDIX B-2

CALCULATION OF DILUTION FACTORS

GZA GeoEnvironmental, Inc.
Engineers and Scientists

Page No.

Project DIGITAL EQUIPMENT File No.

Location SAN GERMAIN PUERTO RICO Date 6/29/95 By DJA

Subject DILUTION FACTORS Checked By

Based on Revised By

$$\text{DILUTION FACTOR} = \frac{C_r - C_s}{C_s - Q_s + Q_r}$$

C_r = Concentration Receptor
C_i = Concentration Source
C_s = Site Flow
Q_r = Receptor Flow (Drainage Area × Infiltration)

Q_s

- Overburden Transmissivity = 0.5 -- 10 ft²/d
  - 0.5 = Topographically high areas
  - 10.0 = Valley area

Assume Valley = 70% of Site Area with (perpendicular to flow W-NW), width = 550 ft.

Then T (overburden) =

$$T = \frac{(550\text{ ft})(0.7)(10\text{ ft}^2/\text{d}) + (550\text{ ft})(0.3)(0.5\text{ ft}^2/\text{d})}{550\text{ ft}}$$

$$= \frac{3850 + 82.5}{550\text{ ft}}\ \text{ft}^2/\text{d}$$

$$= 7.2\ \text{ft}^2/\text{d}$$

- Horizontal Hydraulic Gradient (i) = 0.2 (average)
- Width = 550'

$Q_s = 792\ \text{ft}^3/\text{d}$

$$= \left(792\ \frac{\text{ft}^3}{\text{d}}\right)\left(\frac{7.48\text{ gal}}{\text{ft}^3}\right)\left(\frac{1\text{ day}}{1440\text{ m}}\right)$$

$= 4.1$ GPM

Using MAX Parameters Q = 11.4 GPM

FLOW THROUGH SITE - RECHARGE

Precipitation = 56"/yr
Infiltration = 14"/yr
Watershed of site = 25 acres.

∴ Flow through Site from Recharge:

$$(25\text{ ac})\left(\frac{43{,}560\text{ ft}^2}{\text{ac}}\right)\left(\frac{14\text{ in}}{\text{yr}}\right)\left(\frac{1\text{ ft}}{12\text{ in}}\right)\left(\frac{1\text{ yr}}{365\text{ d}}\right)\left(\frac{1\text{ d}}{1440\text{ m}}\right)\left(\frac{7.48\text{ gal}}{\text{ft}^3}\right)$$

$= 18$ GPM

of Which Rock =

$$T_{rock} = 90 - 18 = 72\ \text{ft}^2/\text{d}$$

$i = .02$

Q_r = Offsite flow = area × infiltration

Distance from Site to Guard House = 1200'
PRECIPITATION = 56", INFILTRATION = 14"

$$df = \frac{(4.1\text{ gpm})}{(4.1\text{ gpm}) + \left[(1200\text{ ft})(550\text{ ft})\right]\left(14\frac{\text{in}}{\text{yr}}\right)\left(\frac{1\text{ ft}}{12\text{ in}}\right)\left(\frac{1\text{ yr}}{365\text{ d}}\right)\left(\frac{1\text{ d}}{1440\text{ m}}\right)\left(\frac{7.48\text{ gal}}{\text{ft}^3}\right)\text{ gpm}}$$

$$= \frac{4.1\text{ gpm}}{4.1 + 11\text{ gpm}}$$

$$df = 0.27$$

TABLE B.16

PATHWAY - SPECIFIC CONCENTRATION LIMITS FOR GROUNDWATER
(Based on ARARs for the Guanahibo River)
Digital Equipment Corporation
San German, Puerto Rico

Contaminants Detected in Groundwater Monitoring Wells at the Point of Compliance	Lowest Water Quality Benchmark for the Guanahibo River (CR) (mg/l)	Dilution Factor in Guanahibo River (dfR)		Concentration at Receptor (Cr) (mg/l)		Dilution Factor at Receptor (dfr) (based on overburden only)	Concentration at Site (Cs), (mg/l) (i.e., at the Point of Compliance)	
		Overburden	Rock	Overburden	Rock		Overburden	Rock
Volatile Organic Compounds								
1,1-Dichloroethane	1.60E+01	0.0003	0.0005	5473.3	3061.0	0.27	201.573	30,610
1,1-Dichloroethene	1.85E-03	0.0003	0.0005	6.33	3.54	0.27	23	4
1,2-Dichloroethane	2.00E+00	0.0003	0.0005	684 1.6	3826.23	0.27	25.197	3,826
Chloroform	1.24E-01	0.0003	0.0005	424	237	0.27	1.562	237
cis,-1,2-Dichloroethene	1.16E+00	0.0003	0.0005	3968.13	2219.21	0.27	14.614	2,219
trans-1,2-Dichloroethene	1.16E+00	0.0003	0.0005	3968.13	2219.21	0.27	14.614	2,219
Methylene chloride	1.25E+01	0.0003	0.0005	42760	23914	0.27	157,480	23,914
Tetrachloroethene	8.85E-03	0.0003	0.0005	30.27	16.93	0.27	111	17
Trichloroethene	8.07E-02	0.0003	0.0005	276.06	154.39	0.27	1,017	154
Metals								
Barium	2.30E+00	0.0003	0.0005	8552	4783	0.27	31,496	4,783
Iron	1.00E-01	0.0003	0.0005	342	191	0.27	1,260	191
Manganese	1.00E-01	0.0003	0.0005	342	191	0.27	1,260	191
Nickel	4.88E-02	0.0003	0.0005	167	93	0.27	616	93

Notes:

1. Concentration at site (Cs) at points of compliance represent Pathway - Specific Concentration Limits (PSCLs) in groundwater. PSCLs in groundwater were calculated for contaminants detected in groundwater collected from monitoring wells at the point of compliance (i.e., W-1, W-6, W-7, BR-308, OW-102, OW-304, OW-401, OW-404U, OW-404L, and OW-405) in 1993 and 1994.

2. The lowest of the water quality benchmarks for water and fish ingestion (for human health) and freshwater acute and chronic (for freshwater aquatic life) was used to calculate PSCLs for groundwater.

3. Cs(overburden) (mg/l) = CR/dfR(overburden)/dfr Cr = concentration at the receptor (i.e., discharging to the Guanahibo River) = CR/dfR(overburden)

   Cs(rock) (mg/l) = CR/dfR(rock)

   where,

   Cs = Acceptable risk-based concentration at the point of compliance (i.e., alternate concentration limit)
   CR = Concentration in the Guanahibo River (To calculate PSCLs, the concentration in the river was set equal the lowest applicable and available water quality benchmark for each contaminant detected in groundwater.)

   Dilution Factors:

   dfR (overburden) = dilution factor for discharge into the Guanahibo River for overburden = Qr/(Qr+Qrock+QR)

   where,

   Qr = Flow at the receptor (i.e., discharging to the Guanahibo River)
   Qr = Q(overburden)+Q(off-site) Q(overburden) = 4.1 gpm
   Q(off-site) = 11 gpm (i.e., off-site recharge to overburden)

   Qrock = Flow in rock = 27 gpm

   QR = Guanahibo River flow (based on 115 cubic feet per second or 51,612 gallons per minute)

   dfR (overburden) = Qr/(Qr+Qrock+QR)
   dfR (overburden) = (Q(overburden)+Q(off-site))/(Q(overburden) + Q(off-site) + Q(rock)+QR)
   dfR (overburden) = (4.1 gpm + 11 gpm)/(4.1 gpm + 11 gpm + 27 gpm + 51,612 gpm)
   dfR (overburden) = 0.0003

   dfR (rock) = dilution factor for discharge into the Guanahibo River for rock = Qrock/(Qr+Qrock+QR)

   dfR(rock) = Qrock/(Qr+Qrock+QR)
   dfR(rock) = Qrock/(Q(overburden)+Q(off-site)+Qrock+QR)
   dfR(rock) = 27 gpm/(4.1 gpm + 11 gpm + 27 gpm + 51,612 gpm)
   dfR(rock) = 0.0005

   dfr = dilution factor at the receptor (i.e., discharging to the Guanahibo River) = Qoverburden/(Qoverburden+Qoff site)

   where,

   Q(overburden) = Overburden flow = 4.1 gpm
   Q(off-site) = Off-site flow = 11 gpm

   dfr = Q(overburden)/(Q(overburden)+Q(off-site))
   dfr = 4.1 gpm/(4.1 gpm +11 gpm)
   dfr = 0.27

TABLE B.15

PATHWAY - SPECIFIC CONCENTRATION LIMITS FOR GROUNDWATER
(Based on Facility Worker Inhalation Exposure to Contaminants in Indoor Air)
Digital Equipment Corporation
San German, Puerto Rico

NONCARCINOGENIC EFFECTS

Target Organ	Contaminant	Target Hazard Index	x Inhalation Chronic RfC (ug/m^3)	= Target Exposure (ug/m^3)	/ Receptor-Specific Exposure Factor (unitless)	= Target Indoor Air Concentration (ug/m^3)	PSCLs (mg/l)
Other	Cis 1,2-Dichloroethene	0.50	1100	5.5E+02	2.3E-01	2,409	8.751
	Trichloroethene	0.50	180	9.0E+01	2.3E-01	394	1.432
	Subtotal:	1.00					

CARCINOGENIC EFFECTS

Contaminant	Target Risk Level	/ Inhalation Unit Risk $(ug/m^3)^{-1}$	= Target Exposure (ug/m^3)	/ Receptor-Specific Exposure Factor	= Target Indoor Air Concentration (ug/m^3)	PSCLs (mg/l)
Trichloroethene	1.0E-06	1.7E-06	5.9E-01	8.2E-02	7	0.026

Notes:

1. In the absence of an agency approved inhalation chronic RfC for Cis 1,2-DCE, we used the inhalation chronic RfC for 1,2-DCE (total) developed by Massachusetts Department of Environmental Protection, October 1992.

2. In the absence of an agency approved inhalation chronic RfC for TCE, we used the inhalation chronic RfC for TCE developed by Massachusetts Department of Environmental Protection, October 1992.

3. Pathway - Specific Concentration Limit (PSCLs) for groundwater (mg/l) = {Target Indoor Air Concentration (ug/m^3) / [Assumed Building Ventilation Rate (m^3/hour) x 1 hour/60 min x Pumping Rate of Process Water (gallons/min) x 3.785 liter/gallon]} * 1000

where,

Assumed Building Ventilation Rate:	two air changes per hour (i.e., 165,000 m^3/hour)
Volume of Building:	110 meters x 75 meters x 10 meters = 82,500 m^3
Pumping Rate of Process Water:	200 gallons/minute

APPENDIX C

LIMITATIONS

APPENDIX C

LIMITATIONS

1. The observations described in this Report were made under the conditions stated therein. The conclusions presented in the Report were based solely upon the services described therein, and not on scientific tasks or procedures beyond the scope of described services or the time and budgetary constraints imposed by the Client. The work described in this Report was carried out in accordance with the Basic Ordering Agreement between GZA and the Client dated June 9, 1995, and GZA's proposal to the Client dated May 12, 1995, as modified by subsequent correspondence dated June 5 and June 27, 1995.

2. In preparing this Report, GZA has relied on certain information provided by municipal officials and other parties referenced therein, and on information contained in the files of regulatory agencies available to GZA at the time of the work. Although there may have been some degree of overlap in the information provided by these various sources, GZA did not attempt to independently verify the accuracy or completeness of all information reviewed or received during the course of this site evaluation.

3. The conclusions and recommendations contained in this Report are based in part upon the data obtained from a limited number of soil and/or groundwater samples obtained from widely spaced subsurface explorations. The nature and extent of variations between these explorations may not become evident until further exploration. If variations or other latent conditions then appear evident, it will be necessary to reevaluate the conclusions and recommendations of this Report.

4. Except as noted within the text of the Report, no other quantitative laboratory testing was performed as part of this design evaluation. Where such analyses have been conducted by an outside laboratory, GZA has relied upon the data provided, and has not conducted an independent evaluation of the reliability of these data.

5. The conclusions and recommendations contained in this Report are based in part upon various types of chemical data and are contingent upon their validity. These data have been reviewed and interpretations made in the Report. As indicated within the Report, some of these data are preliminary "screening" level data, and should be confirmed with quantitative analyses if more specific information is necessary. Moreover, it should be noted that variations in the types and concentrations of contaminants and variations in their flow paths may occur due to seasonal water table fluctuations, past disposal practices, the passage of time, and other factors. Should additional chemical data become available in the future, these data should be reviewed by GZA, and the conclusions and recommendations presented herein modified accordingly.

6. Chemical analyses have been performed for specific parameters during the course of this site evaluation, as described in the text. However, it must be noted that additional chemical constituents not searched for during the current study may be present in soil and/or groundwater at the site.

7. The basis of the preliminary remediation design is limited to those conditions which were discovered in carrying out the assessment of subsurface contamination identified during previous hydrogeologic evaluations of the site. While the preliminary design represents our best professional judgment in this matter, it does not represent an absolute worst-case remedial design. The preliminary design includes only those items identified, and should not be assumed to include other factors such as legal, administrative, or permitting issues which are not specifically addressed in the Report.

8. The design is based on limited data which may not be sufficient to identify each and every condition existing at the site which may constitute noncompliance with applicable governmental statutes, rules, and regulations or constitute a release of oil or hazardous materials.

9. Governmental agencies' interpretations, requirements, and enforcement policies vary from district office to district office, from state to state, and between federal and state agencies. In addition, statutes, rules, standards, and regulations may be legislatively changed and inter-agency and intra-agency policies may be changed from present practices. GZA has used its experience and judgment in making assumptions as to how anticipated changes in enforcement policies may affect remediation design.

APPENDIX D

EQUIPMENT CUT SHEETS

CARBTROL®
CORPORATION

51 Riverside Avenue
Westport, Connecticut 06880
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FAX (203) 226-3322

July 12, 1995

Mr. David Ott
TERRA-VAC, INC.
2 Park Drive Suite 3
Westford, MA 01886

Subject: Remediation Project - Puerto Rico

Dear Mr. Ott:

Thank you for your interest in the CARBTROL Model HP-1700 Liquid Phase Activated Carbon Adsorber.

The HP-1700 Adsorber is engineered to provide you with quick installation and efficient, reliable operation for water flows up to 100 GPM. For larger flows, units can be connected in parallel.

The Model HP-1700 Adsorber has the following:

"Features"	"Benefits"
- Contains 1,700 lb. of carbon.	- High activity carbon results in greater adsorption capability and longer operating life.
- Is constructed wound FRP.	- Corrosion resistant for long field life.
- Has a low pressure drop.	- Only 0.6 psi loss at 75 GPM.

We maintain our adsorption vessels in stock for immediate shipment to your site.

We expect this proposal meets with you satisfaction. Please feel free to contact me to answer any questions you might have not answered by the attached information

Sincerely,

James W. Davidson

James W. Davidson
JWD
Enclosures

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CARBTROL
CORPORATION

July 12, 1995

Mr. David Ott
TERRA-VAC NORTH EAST

QUOTATION

ITEM	QTY	DESCRIPTION	PRICE
1	1	CARBTROL HP-1700 Carbon Adsorber complete with 1700 lbs. of Liquid Phase Carbon.	$8,825.00

Estimated Shipment: One Week From Order
Subject To Prior Sale.

SALESPERSON: James W. Davidson
TERMS: Net 30 Days
COMMENTS: F.O.B. Bridgeport, CT

QUOTATION VALID FOR SIXTY DAYS

JWD

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CARBTROL
CORPORATION

SPECIFICATION
ACTIVATED CARBON ADSORBER
HIGH PRESSURE, LIQUID PHASE

Model:		HP-1000	HP-1700
Design Flow (GPM):		50	100
Design Features:			
Carbon:		Liquidphase virgin activated carbon, 8 X 30 mesh. Iodine No.: >1000.	
Carbon Weight (lbs.):		1000	1700
Adsorber:		Fiber wound epoxy construction, ABS & PVC internal piping. forklift skid base.	
Max. Recommended Operating Pressure (psi):		75 psi	
Dimensions:			
Shell Diameter (in.):		36	48
Overall Height (in.):		86	93
Connections:	Inlet (top):	2" MPT	2-1/2"FPT
	Outlet (bottom):	2" FPT	2-1/2" FPT
	Drain (in outlet piping):	2" FPT	2-1/2" FPT
Shipping Weight (lbs.):		1500	2300
Availability:		1 week	
Drawing Number:		S-1779	S-1863

5/13/94
*SP-420,410/#5

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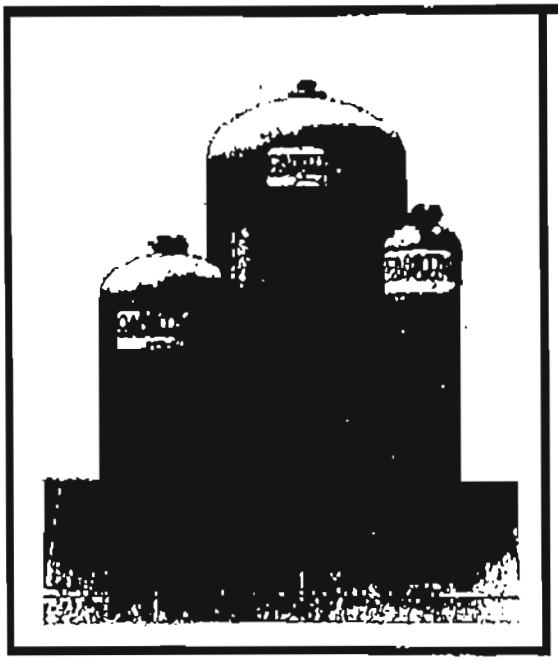
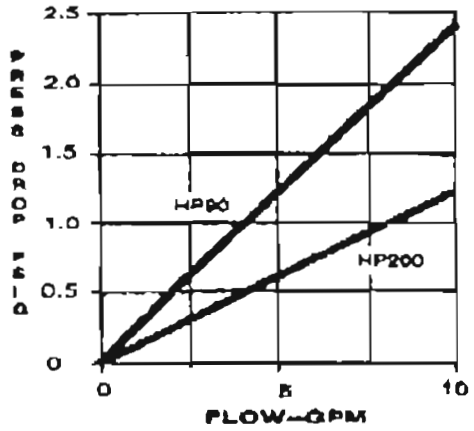
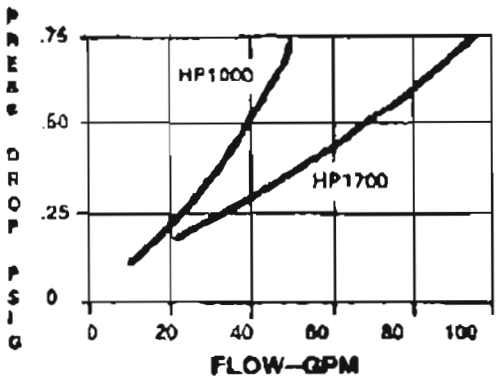


SIZES

MODEL	CARBON QUANTITY	FLOW CAPACITY
HP-90	90 lbs.	10 gpm
HP-200	200 lbs.	10 gpm
HP-1000	1000 lbs.	50 gpm
HP-1700	1700 lbs.	100 gpm





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- Operating pressure from 50-75 psi.
- Corrosion resistant wound fiberglass/ epoxy construction.
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